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MAGNETIC AND IONOSPHERIC DISTURBANCES

Collected Articles Pertaining to Sections III and V of the IGY Program (Geomagnetism and Earth Currents, Ionosphere)

Editor-in-Chief, Yu. D. Kalinin

Translated from compilation made under the auspices of the Interdepartmental Committee for the Conduct of the International Geophysical Year Under the Presidium of the Academy of Sciences of the USSR. Publishing House of the Academy of Sciences USSR (Moscow), No. 1, 1959.

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FOREWORD

During the Fifth Assembly of the Special Committee for the International Geophysical Year, convened in July - August, 1958, in Moscow, several symposia were held in different disciplines of the IGY program. On August 7, 1958, a symposium on geomagnetic and ionospheric disturbances was held, with Prof. A. G. Kalashnikov as Chairman. At that symposium, 18 reports were read by Soviet and foreign scientists.

This booklet presents 12 reports of Soviet scientists, somewhat abbreviated for print.

The reports of Soviet and foreign scientists read at the symposia of the Assembly, shall be issued in Volume X of the Annals of the International Geophysical Year*, published by Pergamon Press in English and French. In this connection, the present publication excludes abstracts of reports in English.

Some authors have added to their reports the most important data obtained after the Assembly.

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* Annals of the International Geophysical Year. Published by Pergamon Press. London, New York, Paris, Los Angeles.

Diurnal Distribution of Active Periods of Magnetic Disturbances at High Latitudes

By A. P. Nikol'skiy

We have shown [1] that the isochrones of the morning maximum of magnetic disturbances in the Arctic constitute a system of spirals emanating from a pole of homogeneous magnetization and unfolding clockwise. We identify these spirals with Shtermer's spiral which involves the settling of solar protons in the earth's atmosphere.

F 4 9

Furthermore, in accordance with Shtermer's theory, and on the basis of an analysis of the results of observations of magneto-ionospheric disturbances and of aurora polaris, it was assumed [2] that four Shtermer zones, A, B, C and D may be present on the earth's surface, wherein the appearance of irregular magneto-ionospheric disturbances (active periods) is timed at 14-15, 20-21, 02-03, and 08-09 hours of local time. The location of these four zones on the surface of the earth was given in the first approximation.

Although certain data regarding phenomena that are caused by the intrusion of solar corpuscles into the upper layers of the earth's atmosphere do confirm the plausibility of the above assumption, it has not been possible so far to establish the most important thing, namely, to show that intervals corresponding to all four Shtermer zones actually do occur during the course of diurnal magnetic disturbances, when the probability of the occurrence of active periods -- irregular magnetic disturbances -- increases.

It is known that at medium geomagnetic latitudes, a clear diurnal maximum in the frequency of appearance of active periods can be recorded at about 14-15 hours local time in a number of stations, and at high geomagnetic latitudes ($\Phi \geqslant 72^{\circ}$) at 07-09 hours local time. These diurnal intervals, apparently, may be interpreted as Shtermer's A and D zones.

However, it was not possible to establish definitely the greater probability of the appearance of active periods of magnetic disturbances at approximately 20 and 02 hours local time (which correspond to Shtermer's B and D zones).

The standard method used up to the present time, which involves a statistical analysis of the diurnal distribution of irregular magnetic disturbances, has a basic defect, the cause of which is concealed in the very principle of statistical averaging (reduction). This defect lies in the fact that, when figures corresponding to a large number of days of magnetic storms are averaged, very smooth curves showing the diurnal distribution of active periods are obtained, and, therefore, it is impossible to detect fine details occurring during the course of magnetic storms. It is known that a magnetic storm is an alternation of successive active periods and intervals of comparative quiet and slackening of irregular disturbances. In view of such a nature of magnetic storms, it is possible to divide days of magnetic storms into groups - for instance, symptomatically as proposed by V. A. Lovtsova. One group includes days of magnetic storms, during which the highest intensity of the active period, evaluated by the hourly amplitude of the horizontal component r_H^γ would occur during the same world time hours.

Such a selection was made for days during which the most active period occurred at 7-8, 9-10, 11-12, 13-14, 15-16, 17, 18-19, 20, and 21-22 world time hours. The analysis was based on magnetic activity data recorded at the Cape Shmidt station (φ = 68°9, λ = 180°5, Φ = 62°8) during 140 days of magnetic storms in 1956.

A selection was made for four separate groups of months in 1956 (January-February; March-May; June-August; and September-December). The number of days selected in each group was small and did not exceed 13 days. For each group the mean diurnal course of magnetic activity was computed according to the hourly characteristic r_H^γ.

The most interesting curves obtained in this manner are presented in Figure 1. They represent several active periods, one of which, the one that is most intense, manifests itself as the result of the actual selection of the days included in this particular group. These curves are remarkable in that the majority of their active periods are timed at 20-22, 02-04, and 06-09 hours of local time. It can be noted that the last active period (06-09 hours local time) corresponds to 18-21 hours world time. The time intervals of the active periods (21-22 and 02-04 hours local time), which have been found, agree well with the time at which active periods corresponding to Shtermer's zones B and C (20 and 02 hours local time) should make their appearance. The third active period of 06-09 hours local time (18-21 hours world time) coincides, within a 1-hour range, with the isochrone of the morning maximum of magnetic disturbances running across Cape Shmidt.

It can be noted that the mean diurnal course of magnetic activity on Cape Shmidt, computed for all the days of 1956 (Figure 2), has one clearly defined maximum at 00-01 hours local time.

However, not in all groups of magnetic storms or on individual days are there three clearly defined active periods; sometimes only two and even one active period can be distinguished. In addition, the appearance of the actual active periods, both on the curves and during individual storms, varies somewhat around their mean moments of appearance (20 and 02 hours local time and 18-19 hours world time). According to Shtermer, this can be explained in the following manner. In case all three active periods are present, this means that streams of solar particles were flowing toward the earth over a sufficiently long period of time, i.e., the spiral of particle precipitation was hanging over the earth's surface during a rather long interval. For instance, in order that an active period may be observed at 20 hours local time (zone B) at Cape Shmidt the corpuscular flow must reach the earth no later than 8 hours world time. If the particle flow towards the earth continues to take place beyond this time, then at 02 hours local time (14 hours world time) zone C will pass over Cape Shmidt, which will cause the appearance of a second active period; and finally, if the corpuscular flow still continues, Cape Shmidt will be located right under the particle spiral, in the spiral section closest to the pole. This will occur at 18-20 hours world time (the morning maximum of magnetic disturbances), as a result of which a third active period will be observed at Cape Shmidt. If the corpuscular flow will continue to take place for several days in a row, then every one of these days should also have three active periods.

What will happen at Cape Shmidt if the corpuscular flow reaches the earth after 8 hours world time? In this case, the first active period, which is due at 20 hours local time, will not be observed at all. If the flow reaches the earth at 14 hours world time and prior to 18 hours world time, then there will be no second active period either. In this case, only the third active period will make its appearance, which will be centered at 18 - 20 hours world time as a result of the passage of Cape Shmidt directly under the sedimentation spiral. Thus, when the corpuscles stop reaching the earth at various hours of world time, this condition will be reflected in the corresponding sequence of disappearance of the various active periods.

The inconstancy of the moments of appearance of active periods from one day to another in each of these three-day periods may be explained, specifically, by the fact that the predominant velocity (hardness) of particles in the velocity spectrum of flows approaching the earth can change from one day to another. This must occur as a result of the fact that the conditions of solar emanation of corpuscles cannot remain unchanged.

Indeed, it follows from Shtermer's theory that the greater is the velocity (hardness) of particles approaching the earth, the further will the sedimentation spiral recede from the pole of homogeneous magnetization. This means that, if on days with an average level of magnetic activity the isochrone-spiral running through Cape Shmidt corresponds to 18-20 hours world time, then on days when the predominant velocities of the flows approaching the earth are greater, an isochrone sedimentation spiral will pass over Cape Shmidt, which will correspond to 20-22 or even later hours of world time.

Thus, the time of formation of active periods depends on two factors: first, on the time at which the corpuscular flow will approach the earth, the duration of the particle flow, and the time at which the particle flow will stop; and second on the velocity spectrum of the corpuscles in the flow, i.e., on the velocity distribution of the particle density in the flow. Since the nature of the above-mentioned parameters of corpuscular flows varies greatly, this is reflected precisely in the very great variety of the course of individual magnetic storms. F 4 9

From the above statements, it follows again that the usual average statistical diurnal course of magnetic activity does not correspond at all to the actual course of magnetic storms and can only be considered as an extremely rough characteristic of such storms.

It may be assumed that a similar study covering an extensive network of magnetic stations will allow to determine more precisely the location (distribution) of Shtermer's A, B, C and D zones.

The obtained results are also confirmed by other observation data. Thus, intense northern lights (aurora polaris) were observed at Tiksi Bay over a period of 7 days during October 1957. Corresponding hourly values of magnetic activity (r_H^δ) were recorded for these days and its mean diurnal course was established (Figure 2). This figure shows that the curve of the diurnal course clearly exhibits the presence of 3 active periods of disturbance: at 20 and 02 hours local time, and at 21 hours world time. The time of these three active periods coincides closely with the time derived from data obtained at Cape Shmidt and coincides well with the moments derived from Shtermer's theory.

It should be noted that the mean annual diurnal course of magnetic activity at Tiksi Bay exhibits the presence of one maximum at 00-01 hours local time (Figure 2).

On the basis of an analysis of observations of the propagation of radiowaves on a slip frequency of 19.0 - 39.5 mgc along the Dikson-Tiksi line in 1956-1957, N. I. Fedyakina [3] showed that, on separate days, an oblique ionospheric probing reveals rather clearly the presence of the following three time intervals in the transmission of the highest frequencies: 18 - 22, 00 - 04, and 07 - 11 hours Tiksi statutory time (the third interval in the transmission of high frequencies corresponds to 16 - 20 hours world time). The good transmission of high frequencies during these periods may be connected with the appearance in the ionosphere between Dikson and Tiksi of clouds with a high rate of ionization resulting from a corpuscular intrusion. The results obtained by N. I. Fedyakina also substantiate the conclusions reached in this article on the basis of magnetic data.

Shtermer's theory on the movement of charged particles in a magnetic dipole field is widely used in studying the trajectories of cosmic rays. The problem concerning the distribution of points on the earth's surface bombarded by cosmic particles ejected by the sun during extensive solar burst periods was studied on the basis of this theory. L. I. Dorman shows in Figure 218 of his book [4], the theoretical distribution of points on the earth bombarded by particles and in Figures 219-221, the results of a comparison with experimental data derived from a study of the distribution on the earth of the effect of cosmic-ray explosions on 19 November 1949, 28 February 1942, and 7 March 1942. It is amazing that, as far as cosmic particles are concerned, these points are also grouped into three diurnal intervals at approximately 20, 03, and 09 hours local geomagnetic time (as a rule, the difference between local geomagnetic time and local time at latitudes below 60° is not very great), and that there is a good coincidence between theoretical and experimental data.

It is known that, during the application of Shtermer's theory to the study of cosmic rays, definite difficulties are experienced in a number of problems and some of the factors observed cannot be explained on the basis of this theory. It is also known that the application of Shtermer's theory to magnetic disturbances, has not yet been generally accepted, since this theory has also resulted so far in great difficulties in explaining certain known facts and phenomena.

However, the results of our studies and, particularly, the conclusions reached in this article in regard to the course of magnetic disturbances force us to turn back again to Shtermer's theory, which, apparently, corresponds most closely to reality.

There are good reasons for assuming that the geographic distribution of points on the earth's surface which are bombarded by cosmic particles during individual solar flare-ups, as well as the geographic distribution of areas subject to the intrusion of solar particles causing magneto-ionospheric disturbances and aurora polaris, can be determined best and most accurately on the basis of Shtermer's theory, in spite of the enormous difference between the energy of cosmic particles and the energy of solar particles. There is no reason to attribute the difficulties experienced in explaining certain facts related to cosmic particles of solar origin and solar particles to the presence in Shtermer's theory of certain fundamentally unacceptable tenets explaining these phenomena. Rather, these contradictions and difficulties are only the result of the fact that actual magnetic and other physical conditions prevailing in the interplanetary space between the sun and the earth, in which the movement of cosmic and solar particles takes place, are different from the conditions which Shtermer assumed in his theory and which are presently assumed during attempts to make use of this theory. Such a possibility is pointed out, for instance, by Bennett [5] and S. B. Pikel-ner [6]. A clarification of this problem constitutes an urgent task for the immediate future.

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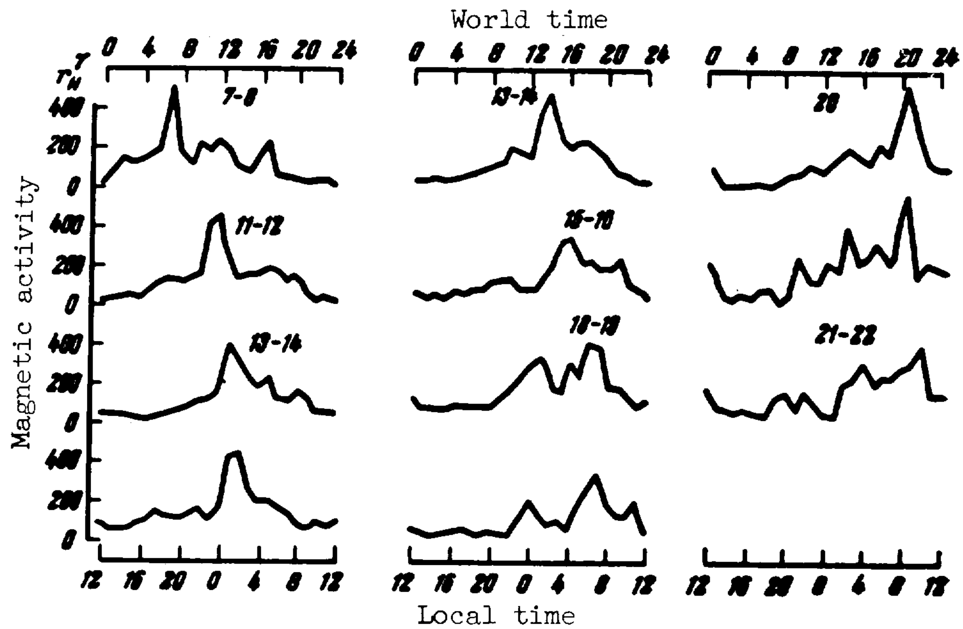
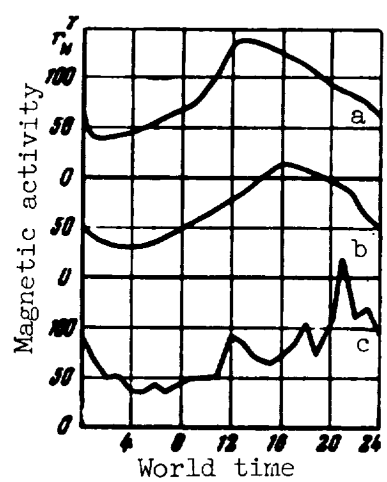


Figure 1.- Distribution of diurnal active periods at Cape Shmidt for selected periods of days with magnetic disturbances.



a - At Cape Shmidt.
b - At Tiksi Bay.
c - On selected days with aurora polaris at Tiksi Bay.

Figure 2.- Mean diurnal course of magnetic activity.

Preliminary Results of the Study of Magnetic Storms During the First Months of the IGY Program

By V. I. Afanas'yeva

A total of 9 very great or great magnetic storms occurred during the first nine months of the IGY (June 1957 - March 1958). During the entire course of 1957, a year of maximum magnetic activity during the current cycle, 13 very great or great large storms took place. During the preceding cycle, the maximum number of very great or great storms (11) occurred in 1947.

There is an opinion prevailing in scientific literature that one of the main characteristics of magnetic storms, connected with the physical properties of corpuscular streams causing magnetic storms, is the type of onset (sudden or gradual) of the storm. It is assumed that the type of storm onset depends on the velocity of the particles [1] and is related to the conditions under which these streams meet the earth ("frontal" or "lateral" impact of the stream against the earth [2]). The author believes that the nature of the storm onset does not constitute a basic characteristic of the storm.

F 4 9

Table 1

Number of Magnetic Storms With A Sudden Onset and of Impulses Without Storms

Type of Storm	Year							
	1949	1950	1951	1952	1953	1954	1955	1957
Very great	4	0	1	0	0	0	0	4
Great	2	4	2	2	1	0	2	4
Medium	10	6	5	3	2	1	0	6
Small	6	3	2	2	1	0	2	9
Impulses	17	10	2	4	5	6	10	7
Total	39	23	12	11	9	7	14	30

On the basis of a study of figures showing the number of sudden onsets of storms and impulses, which are not followed by storms (see Table 1), it is possible to make the following statements:

1) The relative number of storms with a sudden onset does not depend directly on the phase in the cycle of activity.

2) Storms with a sudden or gradual onset may have any kind of intensity.

3) The type of storm onset does not depend on the time elapsing between the moment the storm sets in and the moment in which the central solar meridian crosses the geoeffective region.

F Moreover, a reexamination of magnetograms showed that sudden onsets
4 or impulses occur in most storms and disturbances of any intensity. Thus,
9 storms with a sudden onset are not exceptional instances.

It might be assumed that a sudden onset or impulse is due to a relative difference in the densities of matter within or outside the stream in the immediate proximity of the earth.

The nature of the irregular field section of storms depends to a large extent on the solar location of geoeffective radiation sources. According to E. R. Mustel's [3], magnetic disturbances are caused by the passage of floccules across the solar earth projection. It might be assumed that magnetic disturbances are observed not only during the passage of floccules, but also during the passage of both floccules and spots. The most intense storms are produced by the passage of areas containing spots. Furthermore, as was established by the above author, the presence of a short-period (minute-long) spectrum section D_i is a characteristic feature of storms and disturbances connected with the passage of geoactive formations across the solar earth projection. Figure 1 illustrates a number of examples of such disturbances. Another class of storms and disturbances, in the opinion of the author, includes those which are related to solar formations far removed from the solar earth projection (with heliolatitudes of 20 - 40°). Storms and disturbances of this type are characterized by the absence or weakness (in medium and low earth latitudes) of the aforementioned short-period spectrum section D_i. Fluctuations in storms and disturbances of this type are generally smoother. Examples of disturbances of this type are shown in Figure 2. The division of storms into two classes, according to the nature of D_i and the conditions governing the passage or non-passage of geoactive formations across the solar earth projection, is connected with different conditions of interaction between the geomagnetic field and corpuscular streams.

The intensity of the storm depends on the intensity of the active process occurring on the sun. Very great magnetic storms occurring during years of high magnetic activity are caused by highly active solar regions far removed from the solar earth projection.

The most intense storms which occurred during the expired IGY period (September 1957) were connected with spots and floccules located at latitudes of 10-25° N and lagged by 3-2 days behind the time at which geoactive formations crossed the central solar meridian.

It was noted that solar formations which do not cross solar the earth projection often give rise to storms without an aperiodic variation section (without D_{st}), having a bay (or trough) type at medium latitudes. The geoefficiency of solar regions is higher when such a region is present in one solar hemisphere, and when no such region is present on the same meridian in the other hemisphere.

This is probably due to corresponding peculiarities exhibited by the effect exerted by local magnetic fields of solar regions on the corpuscular radiation yield.

Table 2

Number of Cases in Which Magnetic Disturbances
Are Delayed for Various Reasons

Years	Delay, in Days													
	1	2	3	4	5	6	7	8	9	10	11	12	13	15
1947	1	2	17	21	12	6	1							
1948	1	5	9	21	17	10								
1949		8	12	16	11	4	3							
1950		3	15	12	15	5	2							
1951		2	1	5	11	10	11	9	4	4	1			
1952		2	7	13	17	15	4	3						
1953					2	7	7	4	1	3	1	1	1	
1954				3	5	4	1	1	1					
1955	1		5	16	19	14								
1956	4	3	6	7	1									
1957	7	11	24	4										
1958		6	7	3		1								

An analysis of data concerning storms and solar phenomena occurring during the years 1949-1957 (Table 2) showed that in most cases the geo-effective corpuscular radiation covers the distance between the sun and the earth in 3-4 days during years of high activity, in 5-4 days during years of declining activity, and in up to 12 days during years of minimum activity. There are very few cases in which this distance is covered during the course of a single day. Out of 23 cases of storms and disturbances occurring during the first 6 months of the IGY, this interval was equal to 5 days in 5 cases, 4 days in 8 cases, and 3 days in 10 cases.

The regularities (laws) noted in the nature of a storm may be explained as being due to the relation between the passage of the corpuscular stream past the earth and the prevailing conditions. Low-activity regions "far-removed' from the earth projection give rise to streams which mostly by-pass the earth without creating a current ring (field) near the earth. Regions crossing the solar earth projection give rise to currents encompassing the earth. The magnitude of maximal proximity of the central line of the flow with the earth must be considered as a characteristic parameter of storms.

Table 3

Magnetic Disturbances and Distances (According to Latitude) of Active Regions from the Solar Earth Projection

Type of Storm	Distances of Active Regions From the Solar Earth Projection, According to Latitude						
	0-5°	6-10°	11-15°	16-20°	21-25°	26-30°	31-40°
Very great	5	0	2	0	0	0	0
Great	21	3	4	1	0	0	0
Medium	73	5	3	3	3	2	0
Small	11	3	1	0	0	0	1
Impulses	166	25	14	11	4	3	4
Total	276	36	24	15	7	5	5

Table 3 shows the number of storms or disturbances of varying intensity as a function of the distance of active solar regions, which may be connected with these storms, from the solar projection of the earth.

It can be seen that the majority of storms and disturbances of all intensities are connected with regions lying close to the projection within a range of 0-5° heliolatitude. In addition, it may be seen from Figures 1 and 2 that disturbances have a sudden onset regardless of the conditions under which the earth meets the corpuscular stream. Intensive active storm periods, with high variation velocities of these storms, correspond to a period during which the earth is exposed to streams created by active solar regions with spots. The storms observed in September 1957 represent a confirmation of this fact.

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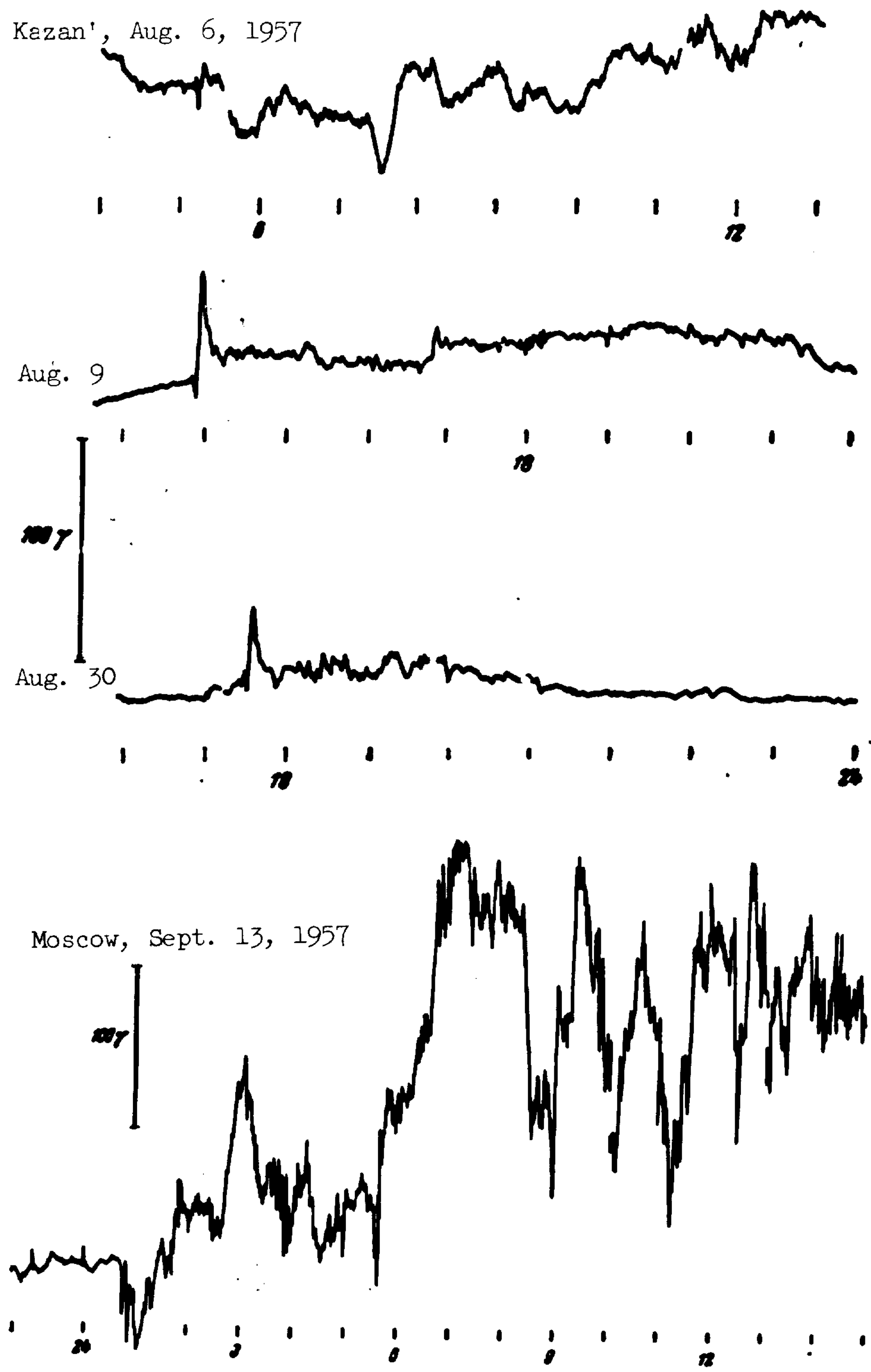


Figure 1.- Disturbances with a short-period spectrum range.

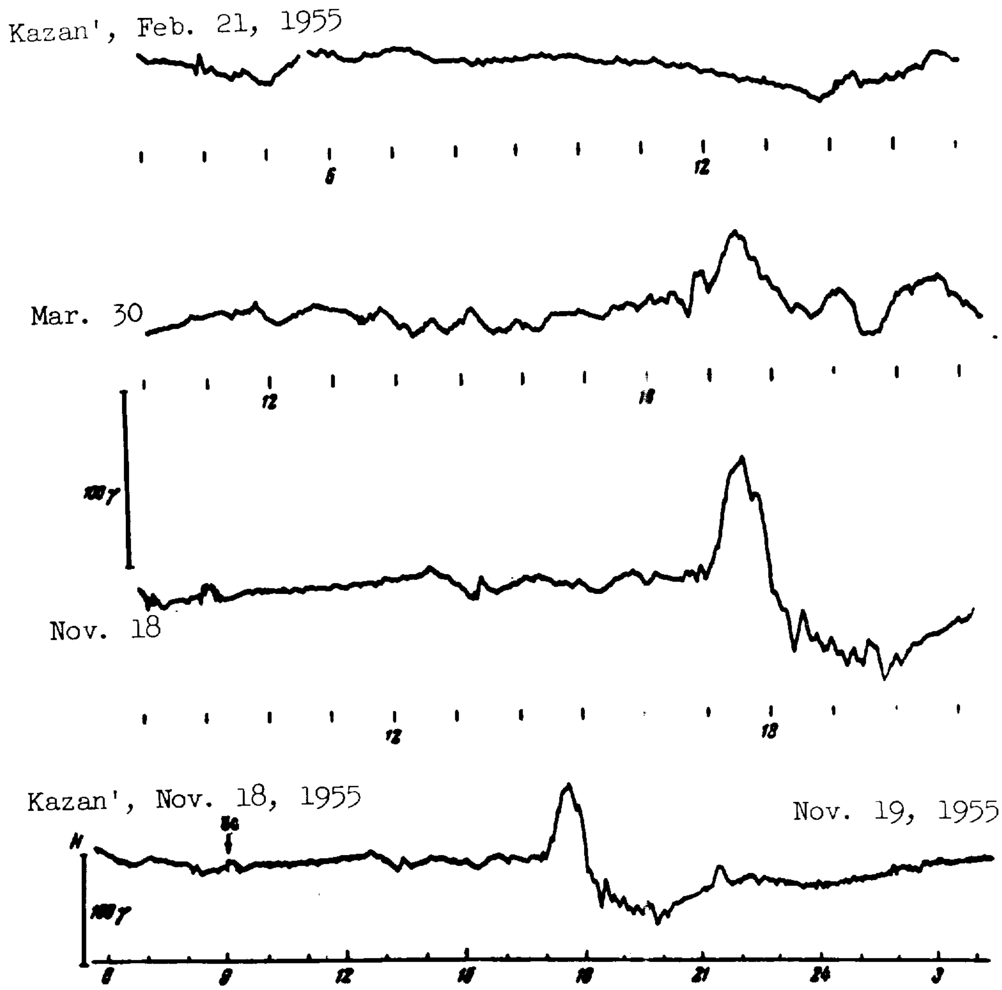


Figure 2.- Disturbances without a short-period spectrum range.

Magnetic Field of Magnetic Disturbances in the Arctic and Antarctic Regions

By B. A. Aleksandrov, M. I. Pudovkin, and B. M. Yanovskiy

A detailed distribution of the field of magnetic disturbances on the surface of the globe cannot be studied on the basis of the data provided by the present network of permanent magnetic observatories, in view of the insufficient number and the non-uniform distribution of such stations. It is possible to conduct such a study by setting up a system of temporarily operating stations, which will record magnetic disturbances during a short period of time in a relatively small area.

The organization of such stations was undertaken for the first time at the Scientific Research Institute for the Geology of the Arctic Region, where, under the direction of B. A. Aleksandrov, continuous observations were conducted during the summer of 1953-1957 at 5 stations located in the north-western Asiatic section of the USSR, in an area lying close to the Arctic region. These stations were located at a distance of 150-200 km from each other and operated every year from March to September.

On the basis of the results of these observations, which so far have only been subjected to a preliminary processing, it is possible to make a number of significant conclusions in regard to the course of bay-like magnetic disturbances. The processing of these observations consisted in determining, for each station, the absolute values of the variations in the vertical (δZ) and horizontal (δH) components of the storm under study, and in plotting these values on charts for various moments of time, followed by the drawing of isolines of the δZ and δH components corresponding to a given moment.

It is necessary to point out that the values of both vector components of the field of magnetic disturbance, derived from magnetograms and plotted on a chart, represent the sum of the components of a field formed by ionospheric and induction currents in the earth. As a result, the difference between the values of the variation vector components, observed at 2 stations, depends not only on the gradient of the field of ionospheric currents, but also on the gradient of the field of earth currents resulting from differences in the conductivity of the earth's crust. However, we are fully justified in assuming that this gradient is considerably smaller than the gradient of external currents, and that the spatial distribution of the magnetic field of variations, represented on charts by means of isolines, must therefore express to a greater extent the field distribution of external currents. A change in the variation field in time, however, is due exclusively to variations of currents in the ionosphere.

Figures 1, 2 and 3 are maps showing the isolines of the δZ and δH components of a bay-like disturbance, which occurred on 23 July 1953, corresponding to the time moments listed in the figure captions.

These maps were drawn on the basis of observation data obtained at the 5 stations set up by the Arctic Geological Institute and at all operating observatories of the Soviet Union, with the exception of southern observatories. Similar charts have been plotted for several dozen storms, which took place during 1953-1957.

A direct examination of the δZ and δH component graphs has shown that the main bay-like disturbances are accompanied by a number of short-period fluctuations, having amplitudes as high as several hundred gammas and half-periods ranging from a few to several dozen minutes. The size
of the amplitudes of such fluctuations is apparently related to the total F
intensity of a particular disturbance, although the size of the amplitudes 4
and their phases are not general characteristics for all the stations 9
from which data were obtained.

For this reason, in plotting isoline charts, the variation curve obtained at each station had to be graphically averaged, since a smooth (reduced) variation apparently reflects the course of the main electromagnetic process occurring in the upper layers of the atmosphere.

On the basis of an analysis of each storm and a comparison of these storms, inspite of a rather rough representation of the variation field for each individual storm, it was possible to draw the following significant conclusions:

1. During the course of a bay-like disturbance, the magnetic field of such a disturbance does not remain stationary, but rather continuously shifts in space, which is already apparent by comparing the maps shown in Figures 1-3.

2. The epicenters (maximum δZ components) of various disturbances are located between the meridians of the Tiksi Bay and Matochkin Shar observatories, and frequently descend South of the Polar Circle.

3. During almost every hour of the 24-hour course of a disturbance, the maximum gradient of the field strength is oriented primarily in a meridional direction. This particular fact has been established for any type of disturbance, ranging from a small-scale disturbance to a violent magnetic storm.

4. The vertical component, and sometimes also the horizontal one, have, in the structure of the disturbance field, adjacent epicenters of both signs, separated by a zero isoline running in a latitudinal or sub-latitudinal direction.

The opposite direction of the variation in the values of field elements shown in Figures 1-3 is precisely due to the fact that one group of magnetic stations is located in the zone of an epicenter of one sign, while the other group is located in the zone of the epicenter having the opposite sign.

5. As a rule, the epicenter corresponding to one sign of the horizontal component includes the vertical component epicenters of both signs and reaches a maximum value on the zero isoline of the vertical component.

6. The numerous charts, showing the isolines of a disturbed field, which were examined indicate that even low-intensity magnetic disturbances arising at high latitudes extend over enormous areas, travelling South as far as medium latitude regions, where their intensity is of practical interest.

7. The variation in the intensity of disturbances in a latitudinal direction has a considerably smaller gradient and exhibits a more uniform character.

As a rule, the intensity of disturbances is considerably lower in north-eastern regions of the USSR. However, simultaneous but apparently independent disturbances are occasionally also observed in these regions, although these disturbances are not connected with the reasons which give rise to disturbances in western regions.

From May to August 1957, M. I. Pudovkin observed magnetic variations at the Mirnyy observatory in the Antarctic region. The data obtained as a result of these observations were compared with the results of a study of ionospheric disturbances, which were observed during the same period with the aid of a vertical probing of the ionosphere.

This comparison led to similar conclusions.

Since an ionospheric station notes the condition of the ionosphere only above the point of observation, while a magnetic station can record variations caused by sources located a considerable distance away, it was necessary, in order to establish their interrelation, to select data corresponding only to those magnetic disturbances caused by sources located above the station.

For this reason, all magnetic disturbances occurring during the period under study were divided into two groups.

The first group included all disturbances in which the amplitude of the vertical component was considerably lower than the amplitude of the horizontal component (in case the field sources are stationary), or in which the sign of δZ undergoes a change during the course of the disturbance (in case the field sources are mobile). (Note: In 85% of the recorded disturbances belonging to the first group, a change in the sign of δZ took place, which indicates that their sources were in motion).

All other disturbances were included in the second group. This group possibly included disturbances whose sources were located at the zenith, but since their shape was distorted by a superposition of a
number of peaks, it was not possible to identify such disturbances with F
a sufficient degree of accuracy. Even when individual disturbances were 4
examined on calm days, errors could have occurred in determining the 9
type of disturbance, since their shape was distorted to a considerable extent by the field of earth currents, which have an exceptionally high intensity at Mirnyy.

Figure 4 shows the average monthly (measured in June 1957) diurnal course of certain ionospheric parameters (minimum reflection frequency f_{min}, the number of appearances of the shielding layer nEs), of the magnetic activity (Q-index) and of the number (nI) of observations of magnetic disturbances belonging to the first group.

The shape of the curves shows a good correlation between the magnetic activity and the condition of the ionosphere. This fact indicates that, inspite of a number of peculiarities typical for the ionosphere in the Antarctic region, the behavior of the ionosphere in this region does not appear abnormal and is subject to the same laws as in the polar regions of the Northern hemisphere.

However, as can be seen from a comparison of the graphs shown in Figure 4, the formation in the ionosphere of a sporadic shielding-type layer Es plays a major role in the occurrence of magnetic disturbances belonging to the first group.

Indeed, a total of 31 magnetic disturbances belonging to the first group were recorded during the above period, of which 28, i.e., 90%, were accompanied by the appearance of the shielding layer Es. At the same time, disturbances also occurred in the F-2 layer. In order to clarify which layer was responsible for the magnetic disturbances (Es or F-2), a more detailed comparison was made between the magnetic field and the ionosphere. For this purpose, tables were drawn up, which listed both magnetic and ionospheric data for every 1/2 hour.

As a result, the figures listed in the table below were obtained.

Month	Magnetic Disturbances of the First Group	Number of Cases Involving: Observations of the Shielding Layer Es	Magnetic Disturbances of the First Group Accompanied by a Shielding Layer Es	Disturbances in the F-2 Layer (see Note 1)
May	5	12	5	91
June	22	21	16	150
July	10	10	9	88
August	10	14	6	86
Total	47	57	36	415** (see Note 2)

Note 1: The term "Disturbances in the F-2 layer" was meant to include a sharp increase in the altitude of this layer and a drop in critical frequency.

Note 2: Out of 415 disturbances in this layer, 321 corresponded to a quiet magnetic field.

It is apparent from this table that the correlation factor corresponding to the number of cases involving magnetic disturbances of the first group accompanied by the appearance of a shielding layer Es (77%) is higher by almost one order than the factor corresponding to disturbances in the F-2 layer (11%).

During the same months, 138 cases of total absorption were recorded, of which 86 corresponded to a quiet magnetic field, and only one case was accompanied by a magnetic disturbance of the first group. This fact indicates that the D layer also cannot be considered to be responsible for magnetic disturbances.

The above statements clearly point out the connection between magnetic disturbances and the appearance of the shielding layer Es. Moreover, the figures listed above indicate that other layers of the ionosphere (such as the F-2 and D layers) are not, apparently, layers in which the phenomena causing the appearance of magnetic disturbances take place.

By comparing data derived from observations of magnetic disturbances at various stations in the Arctic region with data of magnetic and ionospheric observations obtained at one station in the Antarctic region, it is apparent that bay-like disturbances occurring both in the Arctic and Antarctic region have an identical nature, both in regard to their intensity and duration, as well as in regard to the regular relationship between the δ Z and δ H components. For this reason, we are fully entitled to assume that the appearance of these disturbances is due to the same cause.

Data derived from Arctic observations indicate that such a cause involves ionospheric currents having an almost linear shape extending in a latitudinal direction. At the same time, the current line can shift in a meridional direction during the course of a storm, descending to a latitude of 65°.

The cause leading to the formation of such currents can be established on the basis of data derived from Antarctic observations. Most likely, the movement of the sporadic layer E in the geomagnetic field constitutes such a cause.

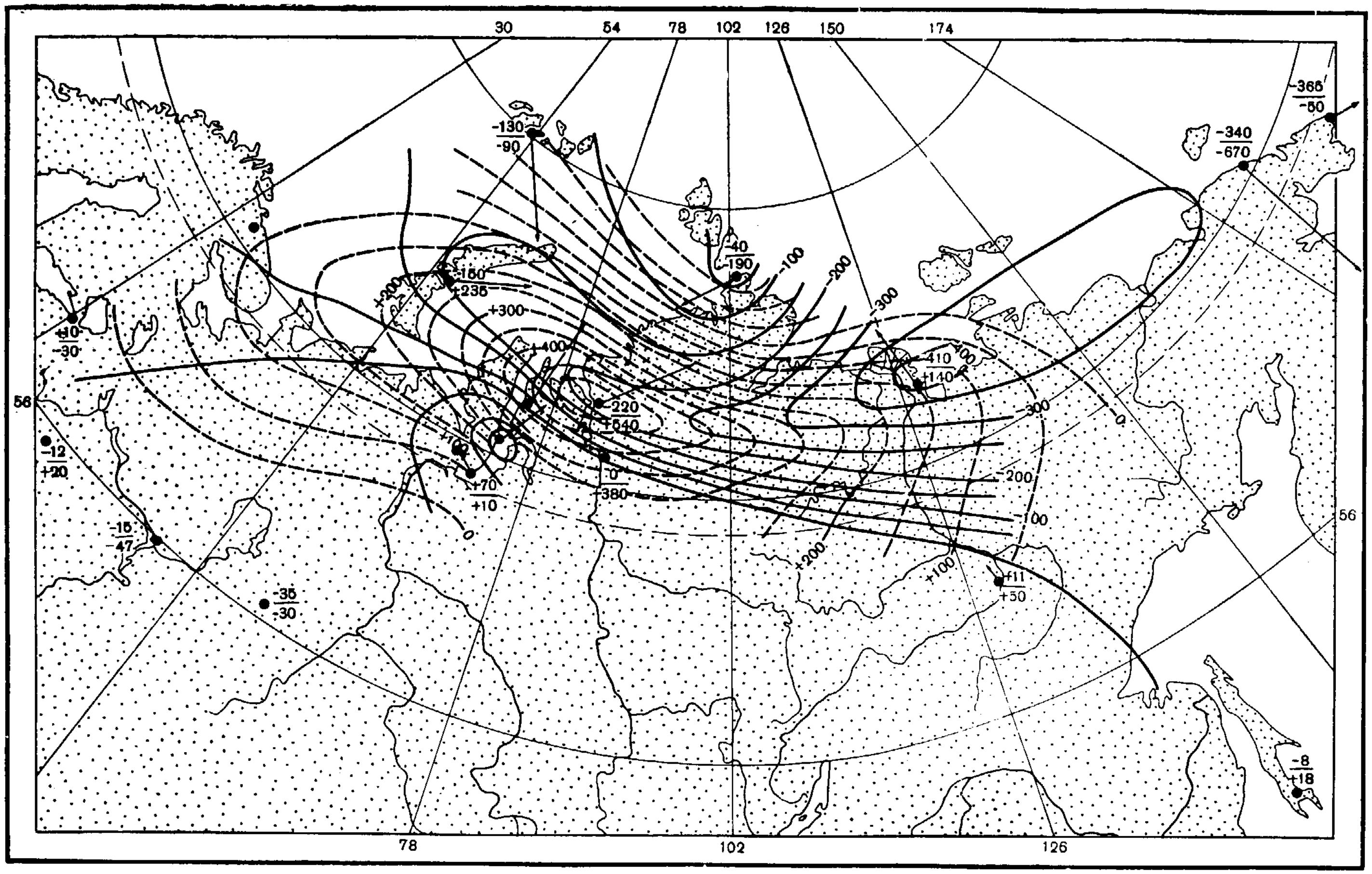


Figure 1.- Isolines of the δZ and δH components of the magnetic disturbance on July 23, 1953, at 09:35 hours. The black dots represent the permanent magnetic observatories and the temporary variation stations, the data of which were used in drawing this chart. The numbers standing next to the observatories are to be interpreted as follows: the numerator gives the value of δZ in gammas, the denominator gives the values of δH in gammas. Solid isolines correspond to δZ, broken lines correspond to δH, and the arrows next to the observatories give the direction of the δH vectors.

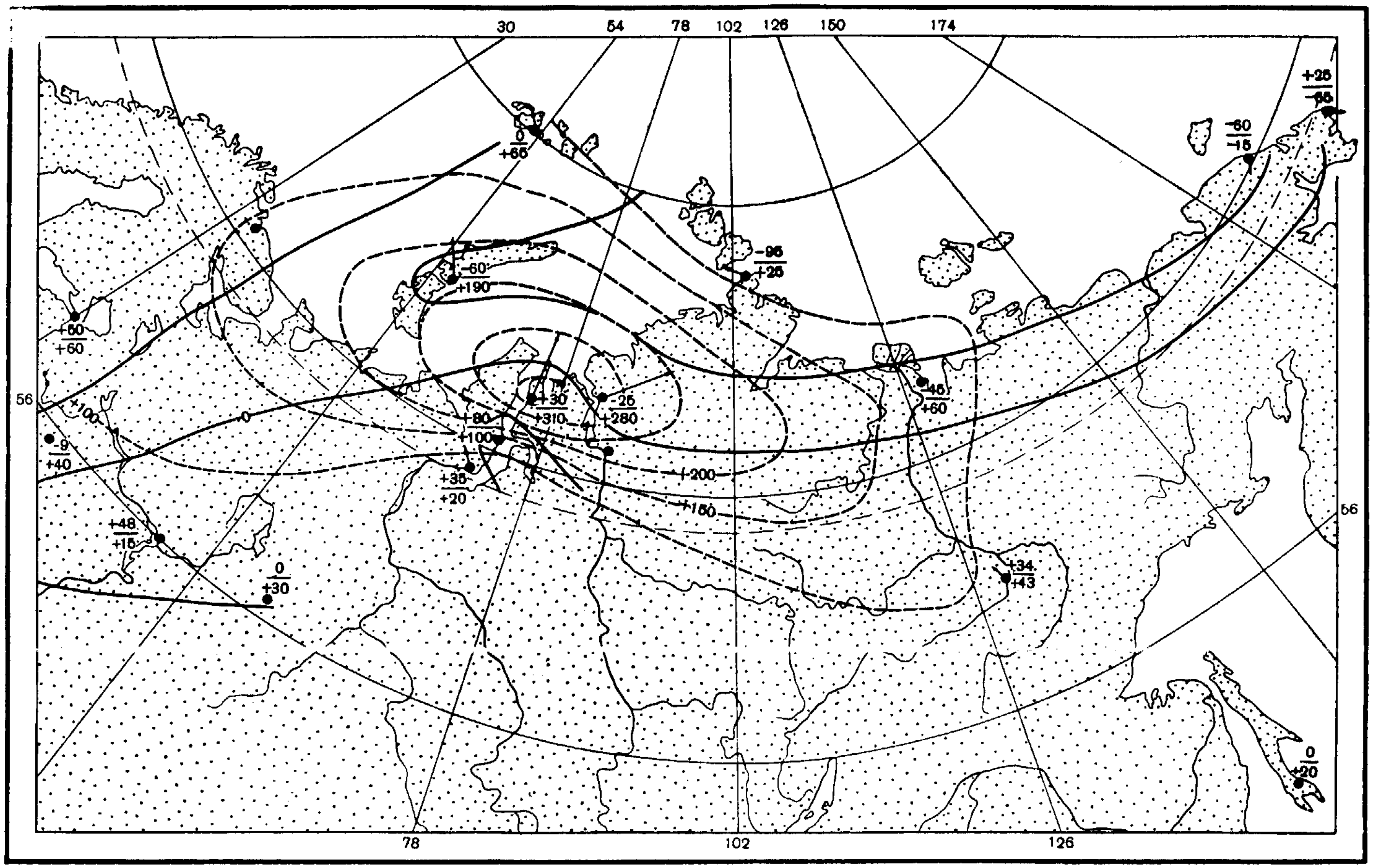


Figure 2.- Isolines of δZ and δH, for the disturbance which took place on July 23, 1953 at 12:50 hours. (Legend same as in fig. 1.)

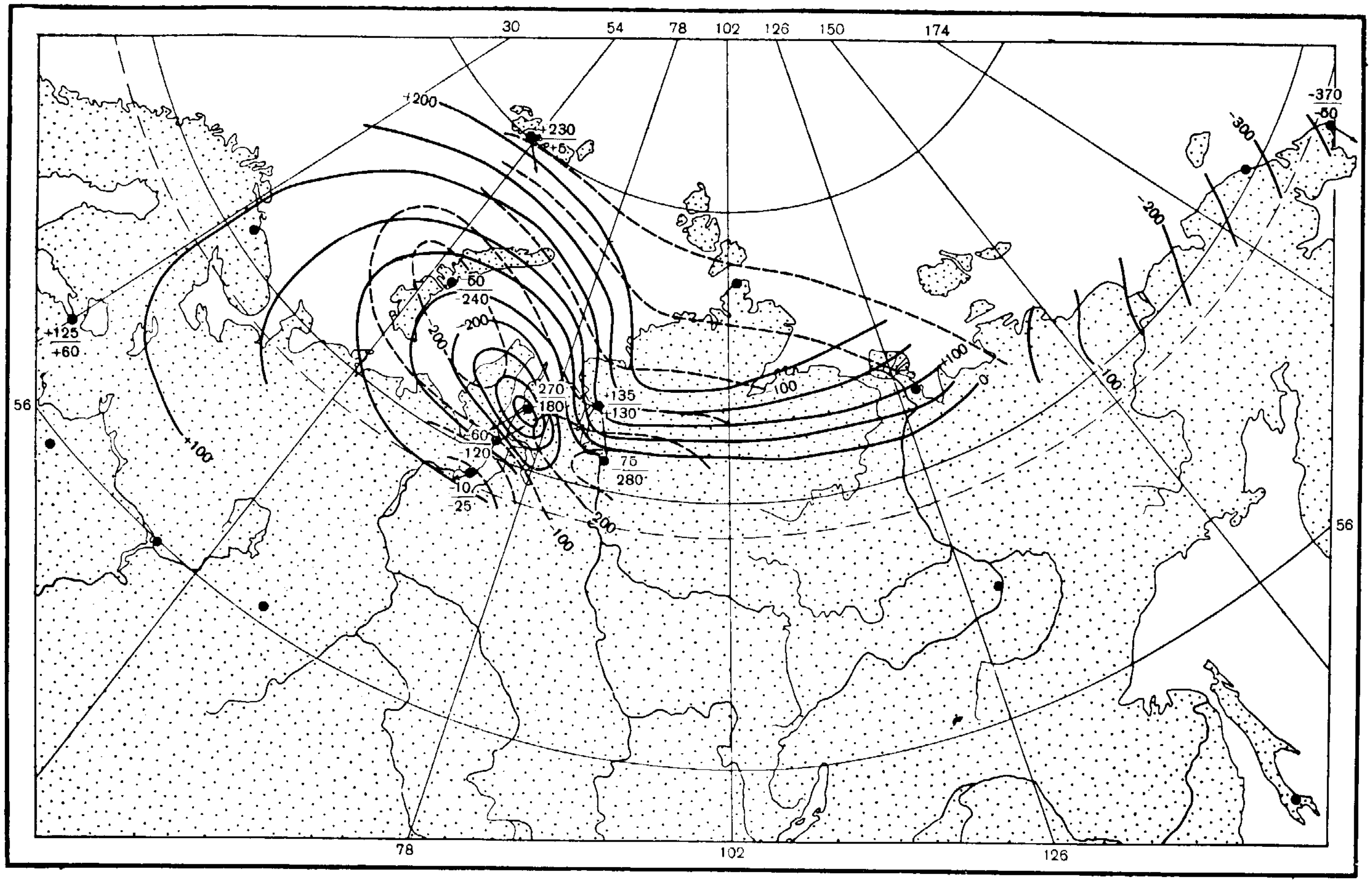
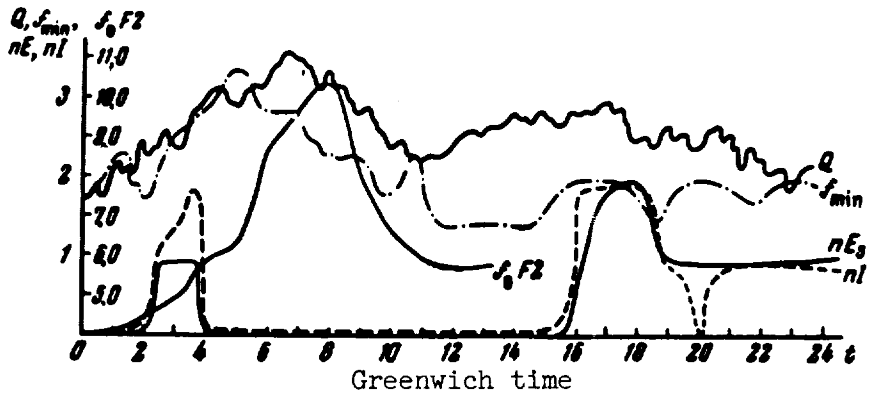


Figure 3.- Isolines of δZ and δH, for the disturbance which took place on July 23, 1953 at 16:10 hours. (Legend same as in fig. 1.)



nEs - Number of appearances of shielding layer Es.

nI - Number of magnetic disturbances of the first group.

Q - Index of magnetic activity.

Figure 4.- Diurnal course of ionospheric parameters and magnetic activity during June 1957.

Preliminary Results Obtained During A Study of the Microstructure of the Most Violent Magnetic Storms, Based on Short-Period Oscillations (see Note)

By V. A. Troitskaya

The study of the microstructure of magnetic storms, based on short-period oscillations (SPO), which was conducted during the first 8 months of the IGY program, had the following purpose:

1. The establishment of additional characteristics, which could be used in a detailed classification of storms.

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2. The determination of characteristic and special periods within a storm, which could be used in studying the interrelation present in the course of disturbed periods within the general complex of electromagnetic phenomena.

3. The determination of parameters (oscillation periods, their sequence, etc.) which could be used and must be taken into consideration during theoretical elaborations of a mechanism representing the course of disturbed periods in the electromagnetic field of the earth.

An analysis was conducted during several most violent storms which occurred on 2-3, 4, 13, 21, 22, 23 and 29 September 1957, and on 11 February 1958; and also during 2 storms of lesser intensity (on 29 September and 6-7 November 1957). All these storms occurred during the first 8 months of the IGY program. Studies were conducted on ultra-speed 24-hour recordings of earth currents with a scanning of 1/2 mm/sec at stations located in the Arctic and Antarctic regions and under medium latitudes in the Soviet Union.

During the course of the study of the storm, the structure of a sudden onset (sc) was established on the basis of the SPO, as well as characteristic time intervals during the course of the storm, during which oscillations of different type and periodicity took place. Characteristic

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(Note: The author wishes to express her deep gratitude to scientific associates working at the Station for Earth Currents, whose recordings were used in the present report, and primarily to the following persons: M. V. Okhatsimskaya, L. N. Baranskiy, I. V. Fel'd, V. V. Kebuladze, P. A. Vinogradov, P. A. Bondarenko, R. V. Shchepetnov, I. I. Rokityanskiy and Yu. V. Rastrusin.).

stages, established for each storm, were then tracked through the entire station network. The microstructure of the storm, based on SPO's, was determined for a period range of 1-30 seconds. Preliminary results of this analysis are listed in the Table on pp. 27 and 28.

On the basis of the data given in this table, the following points might be noted:

1. As a rule, the microstructure of the sudden onsets examined in connection with the above-mentioned storms had a more or less intensive oscillatory nature (2-4 oscillations), with a period generally lying within a range of 8-15 sec. Ocillations (with T = 10-15 sec.) representing a fine structure of the sudden onset which occurred on 22 September exhibited a correct and regular character, particularly at medium latitudes (Figure 1). An exception is the case of the sc which took place on 11-12 February, F
when the sc was expressed by a series of irregular short-period oscilla- 4
tions with periods of 4-7 sec, superimposed on intensive oscillations 9
with T = 20-40 sec.

2. In regard to the main storm stages, it is possible to state that the storms examined differ from each other in their basic structure. On the basis of available data, these storms can be divided into two groups: the first group includes storms, in which the main oscillations making up the storm (storm elements) have very small periods of 2-6 seconds, whereby the shape of these oscillations may be both regular, almost sinusoidal, as well as irregular. The second group includes storms, in which the basic SPO storm stages consist of stable pc-type oscillations (Figure 2a and b).

The first group includes the storms which occurred on 2-3, 4, 13 and 22 September. The second group includes the storms of 21 and 23 September. In the case of storms of 29 September and 6-7 November, their first stage corresponds to the stage of the first group, and in their second stage a transition to the second group was observed (i.e., a transition to stable oscillations).

The analysis of the storm of 29 September (see Table) was conducted on the basis of data obtained at 2 Arctic stations (Cape Chelyuskin and Lovozero), 7 medium latitude stations (Uzhgorod, L'vov, Borok, Alushta, Ashkhabad, Alma-Ata and Petropavlovsk-Kamchatskiy), and 2 Antarctic stations (Mirnyy and Oazis). Thus, for the above stations, the difference in latitude amounted to 144°, and the difference in longitudes amounted to 136°.

The analysis of the storm of 4 September (see Table) was based on data obtained from one Arctic station (Lovozero) and 4 medium-latitude stations (Borok, Petropavlovsk-Kamchatskiy, Alushta (see Note) and Ashkhabad). (Note: The first stage of this storm at Alushta exhibits oscillations with a long period).

Preliminary Data on the Microstructure of the Most
Violent Magnetic Storms During 8 Months of the IGY Program

Date	Sudden Onset and Its Structure				Stages I			
	World Time hours-minutes	A (Type of Amplitude)	T (period), sec.	Type of Oscillations	Interval in World Time, hours-minutes	Duration of Stage, hours	T (period) sec.	Type of Oscillations
1957 Sept 2-3	03-15	Medium	8-10	RO- (Oazis, T=18sec.)	19-01	6	2-3	IO with super-position (Alushta Lovozero) T=6-8sec
4	12-59	"	5-8	RO	13-19	6	2-4	SPO, not pc (Alushta T_{av}=10 sec)
13	0-46	High	10-12	RO	0-46 to 11-10	10-11		IO
21	10-05	"	10-14	RO	10-14	4	10-15 3-4	pc type
22	13-44	"	10-14	RO	13-44 to 16-15	2.5	6-10 2-4	IO
29	0-15	Medium	12-14		4-7	3	10-15	pc type
1958 Feb. 11	01-25	High	20-40 4-7	Intense IO with SPO Super-position	1-25 to 7-00	6.5	3-8	Intense SPO

Remarks: RO - Regular oscillations;
IO - Irregular oscillations;
SPO - Short-period oscillations;
pc - Stable oscillations

Microstructure Table (Concluded)

	Stages							
	II				III			
Date	Interval in World Time, hours, minutes	Duration of Stage, hours	T (Period), sec.	Type of oscillations	Interval in World Time, hours-minutes	Duration of Stage, hours	T (Period) sec.	Type of Oscillations
1957 Sept 2-3	6-18	12	2-6	SPO not pc				
4	18-22	4	1.5-2	Pearls	22-05	7	2-4	High-frequency oscillations
13	10-16	6	1.5-2	High-frequency oscillations	16-30 to 19-30	3 (scattered at various stations within this range)	2.5	Pearls
21	14-17	3		Quiet field	17-00 to 21-30	4-30	1-2	"
22	2-40 to 5 5-6	3.5 1	2-6 10-12	Various mixed oscillations of pc	8-9	1	3-4	"
29	7-10 10-14	3 4	10-14 10-14	Quiet field, pc	17 to 20-30	3.5	2-2.5	"
1958 Feb. 11	7-9 9-14	2 5	4-10	Quiet field, SPO	Mainly 14-16	2	1.5-2	"

Note: See page 27 for oscillation legend.

3. In studying the final stage of the above-mentioned storms according to their SPO characteristics, it was found that, for all 7 storms, the SPO decline of the storm is connected with the appearance of characteristic high-frequency short-period oscillations (see Note). (Note: These characteristic SPO intervals correspond approximately to a phase of maximum field disturbance during the storm, i.e., the K-indices are approximately equal to 8-9).

In case of 5 storms (on 4, 13, 21 and 22 September 1957, and on 11 February 1958), these oscillation intervals terminate in the form of striking oscillations of the throbbing type, known as "pearls". In view of their beauty and peculiar shape, oscillations with periods of 1.5-4 seconds were designated as "pearls" (Figure 3).

In two cases (on 2-3 and 4 September), the end of the storm coincided with the appearance of oscillations with periods of 2-6 and 2-4 seconds. The less intensive storms of 29 August and 6-7 November did not have such a sharply expressed interval of high-frequency oscillations during the course of the storm.

It is interesting to note that the characteristic SPO intervals (with periods of 8-1 sec,), which terminate in the form of oscillation throbs, were found to coincide, on the basis of preliminary results, with the appearance and development of Northern lights (aurora polaris) at low latitudes.

Conclusion

On the basis of the above analysis of the microstructure of storms based on short-period oscillations, the following facts were established:

1. Different storms have a different structure of short-period oscillations.

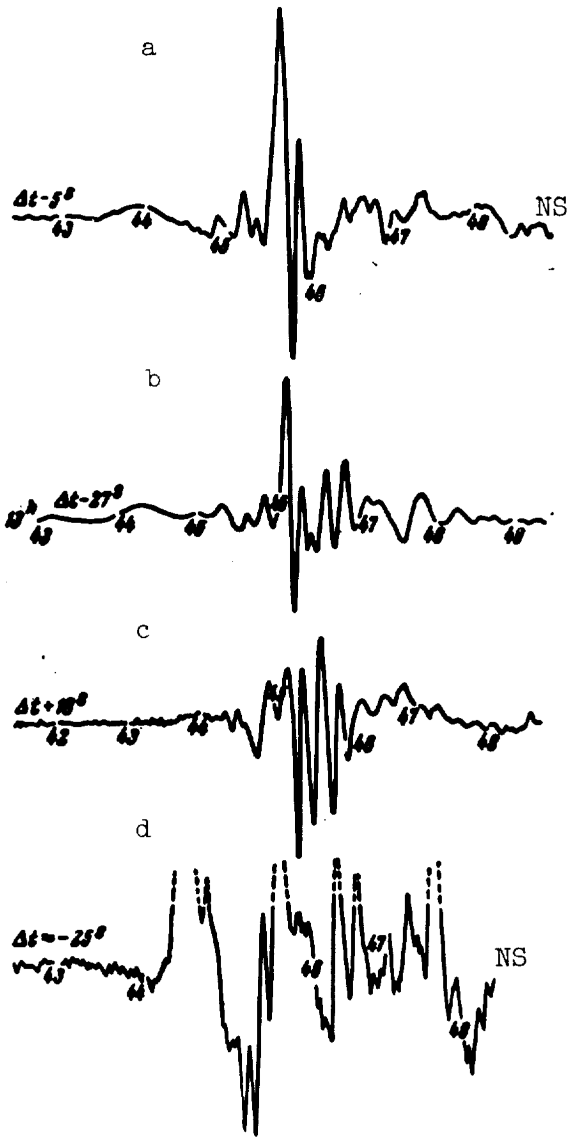
2. The most violent storms which occurred during the first 8 months of the IGY program may be included, in a first approximation, in one of the following two groups: storms with dominant oscillations of very short periods (2-6 sec.), or storms in which the dominant oscillations making up the storm are stable oscillations with a period of 10-15 seconds.

3. In most cases examined, the microstructure of sudden onsets preceding the storm consisted of more or less intensive oscillations (2-4 oscillations) with a period of 8-15 seconds.

4. An important feature of the violent storms which were studied involves the stimulation (excitation), during the course of the storm, of characteristic short-period oscillations of the throbbing type (pearls with $T = 1$-4 sec.), coinciding, on the basis of early preliminary results, with the appearance of aurora polaris at low latitudes.

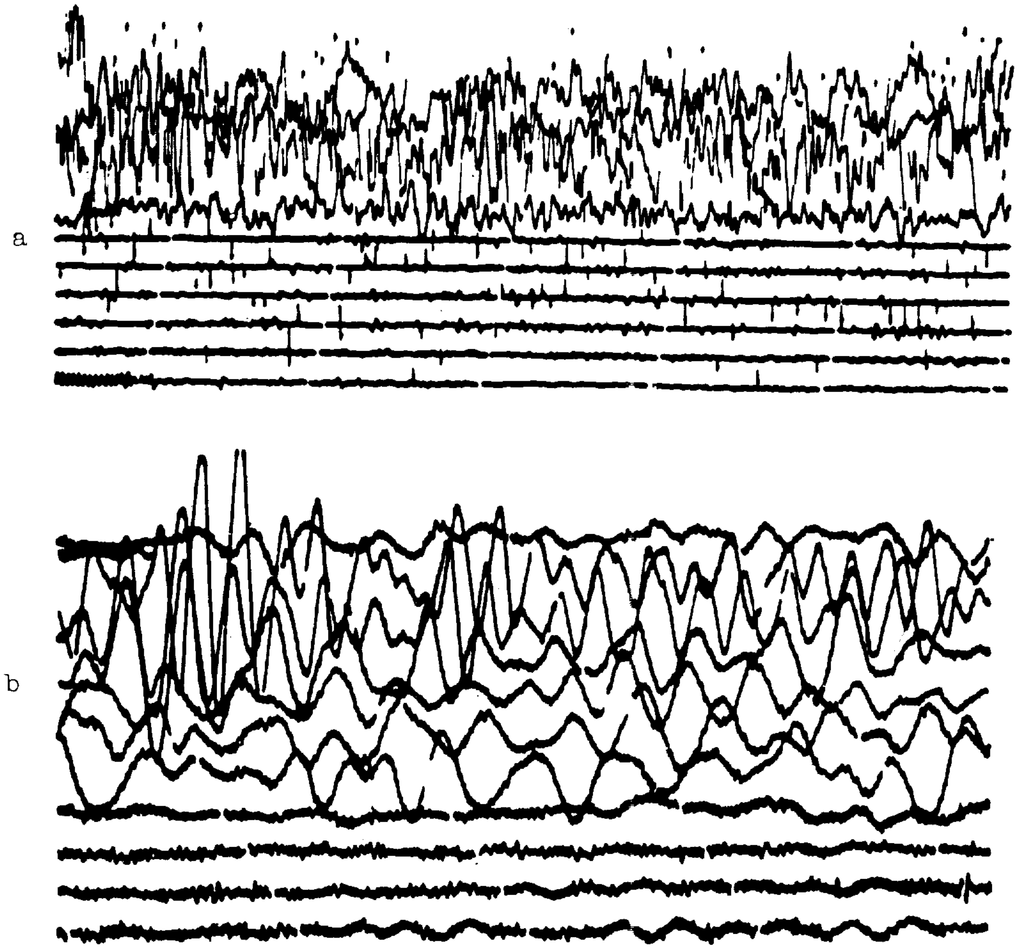
5. The main stages of the storms, based on short-period oscillations, can be tracked with certain modifications at all stations mentioned above (Arctic and Antarctic region, medium latitudes, Far East). It is possible to differentiate storms, for which the main SPO stages can be accurately tracked at different stations, as well as storms for which a coincidence of stages cannot be observed with the same degree of sharpness.

6. As a result of the discovery of these peculiar features in the course of basic storms, it is possible to utilize these new experimental facts in conducting an analysis of the interrelation between the combined various aspects of electromagnetic phenomena occurring during the course of a storm (for example, the development of aurora polaris at low latitudes).



a - Borok station.
b - Uzhgorod station.
c - Alushta station.
d - Mirnyy station.

Figure 1.- Microstructure of the sudden onset of the storm on September 22, 1957, according to recordings with a scanning of 30 mm per minute. Figures on the left indicate the time correction in seconds.



a - Short-period oscillations with T = 2 to 6 seconds.
b - Stable-type oscillations with T = 15 to 25 seconds.

Figure 2.- Elements of microstructural storms (based on recordings with a scanning of 30 mm per minute).

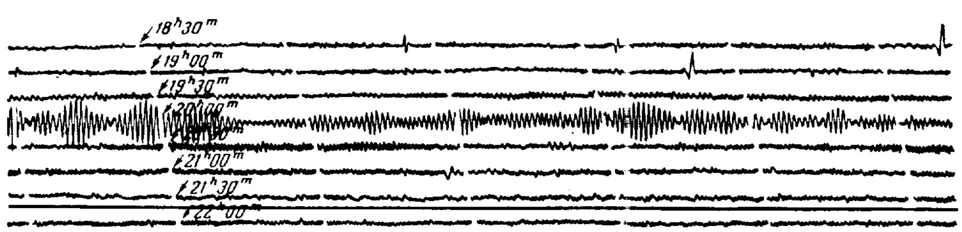


Figure 3.- Example of pearl-type oscillations (on a recording with a scanning of 30 mm per minute). Oscillation period 2 seconds.

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Concerning Methods Used in Effecting A Comparison of Magnetic Disturbances in the Arctic and Antarctic Regions

By A. P. Nikol'skiy

In analyzing the results of observations of magnetic disturbances, it is necessary to effect a comparison of the magnetograms obtained at Arctic and Antarctic stations. In this connection, the following problem must always be considered: with what stations in the Arctic region can a given Antarctic station be compared, in order to make the comparison most effective? Obviously, it is not possible to select a station for this purpose on the basis of close geographic coordinates, since the peculiarities of the course of magnetic disturbances are primarily determined by the geomagnetic latitude. However, the selection of a station based on the distinctive features of a close geomagnetic latitude may also prove to be unsatisfactory, in view of the fact that longitudinal effects apparently play a definite role in the course of magnetic disturbances. For example, an attempted comparison of magnetograms obtained at the Mirnyy station ($\varphi = 66.6^{\circ}$ South, $\lambda = 93.1^{\circ}$East, $\Phi = 77.0^{\circ}$) with magnetograms obtained at Tiksi Bay ($\varphi = 80.3^{\circ}$North, $\lambda = 52.8^{\circ}$ East, $\Phi = 71.5^{\circ}$) proved to be unsuccessful, although the geomagnetic coordinates of these stations are relatively close.

In this connection, it is possible to make a number of suggestions on the basis of conclusions derived from a study of magnetic disturbances, reached at the Arctic Institute. We have shown (1) that the isochrones of the morning maximum of magnetic disturbances in the Arctic region constitute a system of spirals emanating from a uniform magnetization pole and unwinding (extending) in a clock-wise direction (Figure 1). We believe that it is possible to utilize this rule in determining Arctic and Antarctic stations, the observation data of which can be recommended for comparison purposes, and specifically, for effecting a comparison of magnetic disturbances which result in the formation of a morning maximum.

From Shtermer's aurora polaris theory, it can be deduced that isochrones in the Antarctic region, which represent particle precipitation spirals, must unwind (unroll) in a counter-clockwise direction, in view of the fact that morning disturbances, judging from Arctic observations, are apparently caused by positive particles, most likely consisting of protons. On the basis of the following observation data obtained at Antarctic stations, listed in an article by Stagg (2): Cape Evans ($\varphi = 77.6^{\circ}$ South; $\lambda = 166.4^{\circ}$ East; $\Phi = 78.9^{\circ}$), Cape Denison ($\varphi = 67.0^{\circ}$ South; $\lambda = 142.7^{\circ}$ East; $\Phi = 75.5^{\circ}$) and Gauss's Land ($\varphi = 66.0^{\circ}$ South; $\lambda = 89.6^{\circ}$ East; $\Phi = 76.1^{\circ}$), we have plotted an isochrone system for the Antarctic region (3), which is symmetrical with Arctic isochrones.

At the present time, P. K. Sen'ko (4) has completed the processing of magnetic observations conducted in 1956-1957 at the Mirnyy station. It was found that the time at which the morning maximum of magnetic disturbances sets in at that station coincides, with an accuracy of up to 1 hour, with the isochrone drawn at an earlier date for the region where the Mirnyy station is located, when the results of observations conducted at this station were not yet available. This fact indicates that the isochrones corresponding to the onset of the morning maximum of magnetic disturbances in the Antarctic region apparently correspond to actual conditions.

Figure 2 shows a map of the Antarctic region on which isochrones of the morning maximum of magnetic disturbances have been plotted. The dots on this map represent 30 Antarctic stations, in which magnetic observations according to the IGY program were conducted in 1957.

If the Arctic and Antarctic isochrone charts are used as a reference, then, apparently, the magnetograms of the Mirnyy station should preferably be compared with magnetograms obtained at stations located on the northern and western shores of Iceland, or on the east coast of Greenland between 65 and 75° North geographic latitude. Accordingly, when comparing other stations, it is necessary to proceed from the location of stations in relation to isochrones of the morning maximum of magnetic disturbances.

At present, when the observation data of Antarctic magnetic stations operating under the IGY program are already in the processing stage, it would be very important to check how closely the observation data coincide with the isochrones plotted for the Antarctic region.

TABLE

Magnetic Stations in the Antarctic Operating in 1957
According to the IGY Program

Serial No.	Name of Station	Latitude	Longitude
1	Mirnyy	66°33'S	93°00'E
2	Oazis	66 16	100 43
3	Pionerskaya	69 44	95 30
4	Komsomol'skaya	74 05	96 29
5	Vostok	78 27	106 52
6	Little America	78 11	162 10 W
7	Bird	79 59	120 01
8	Ellsworth	77 43	41 08
9	Amundsen-Scott	90 00	-
10	Wilkes	66 15	110 31 E
11	Argentina Islands	66 15	64 16 W
12	Holly Bay	75 31	26 36
13	Dumont D'Urville	66 40	140 01 E
14	Charcot	69 23	139 02
15	Kerguelen Island	49 20	69 16
16	Mawson	67 36	62 53
17	Davis	68 35	77 58
18	Macquarie Island	54 29	158 58
19	Scott	77 51	166 45
20	Cape Adare	71 30	170 24
21	Campbell Island	52 33	169 09
22	Queen Maud Land	70 30	2 32 W
23	Siowa	69 00	39 35 E
24	Deception Island	62 59	60 43 W
25	Esperanza	63 16	56 49
26	Ushuaia	54 48	68 19
27	Arturo Pratt	62 30	59 41
28	Punta Arenas	53 10	70 55
29	Marion Island	46 51	37 45
30	General Belgrano	77 58	38 48

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4. Sen'ko, P. K. "Magnetic Observations at the Mirnyy Observatory" Trudy Kompleksnoy Antarkticheskoy Ekspeditsii (Transactions of the Combined Antarctic Expedition), 1958.

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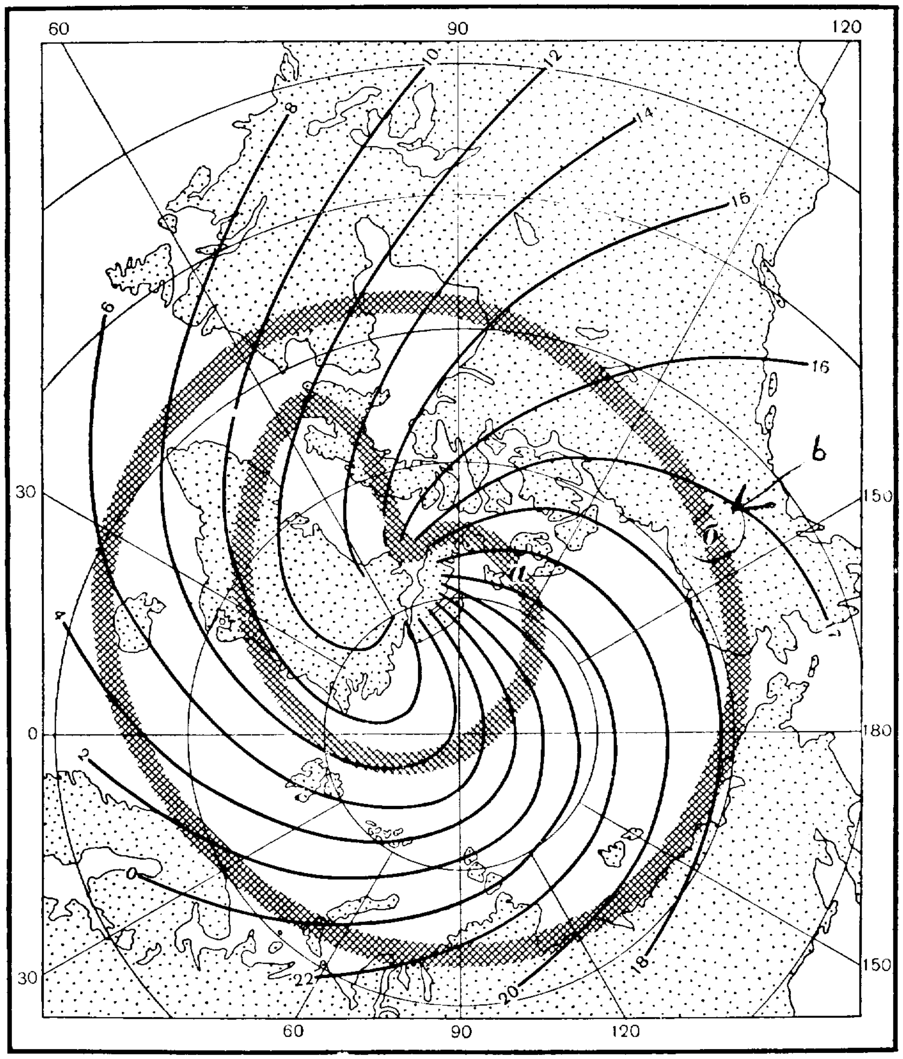
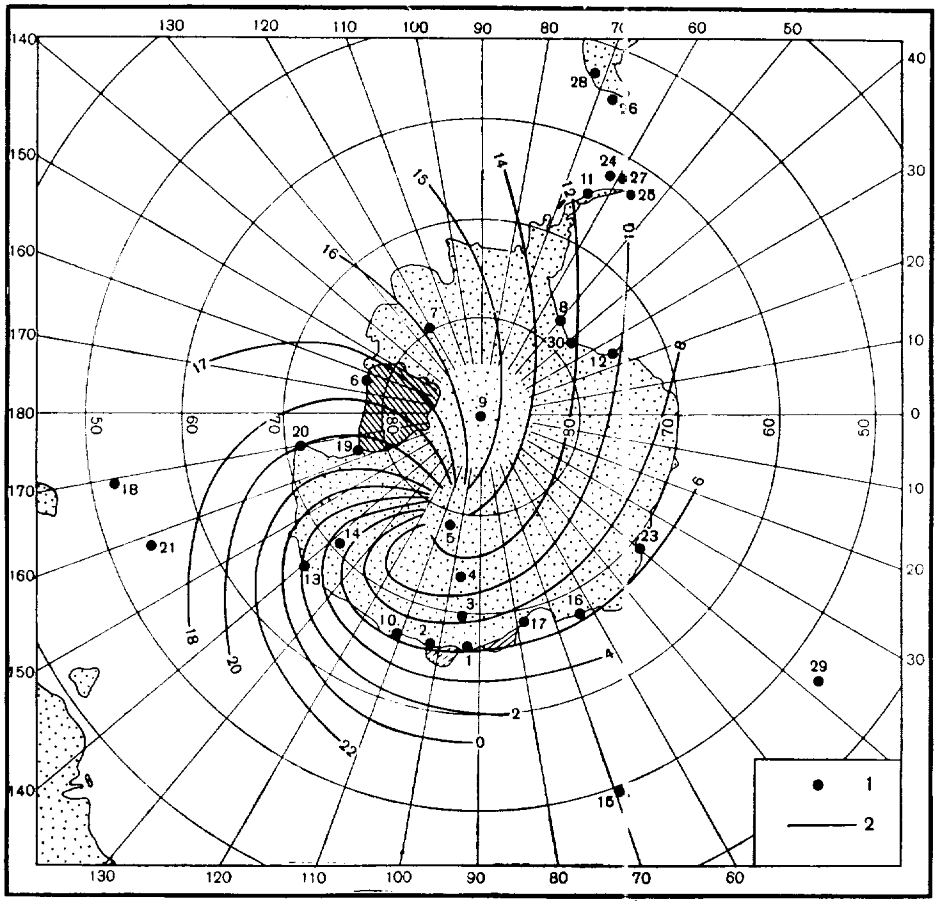


a - Second zone of high intensity and recurrence of magnetic disturbances.
b - First zone of high intensity and recurrence of magnetic disturbances.

Figure 1.- Isochrones of the morning maximum of magnetic disturbances in the Arctic (world time).



1 - IGY station performing magnetic observations.
2 - Isochrones of the morning maximum of magnetic disturbances.

Figure 2.- Isochrones of the morning maximum of magnetic disturbances in the Antarctic (world time).

Ionospheric Disturbances at Medium Latitudes

By N. V. Mednikova

Introduction

The study of disturbances is one of the main problems in the IGY ionospheric research program. This problem is very complex, and for this reason has not been investigated to a great extent, although it has been the subject of numerous studies.

The extensive observation data collected during the IGY program will afford great possibilities for the study of disturbances. Therefore, it would be very desirable to discuss a number of basic problems concerning the methods used in the study of disturbances, such as the problem of criteria of ionospheric disturbances, the method of identifying ionospheric disturbances according to ionospheric data, the classification of disturbances according to types, the basic characteristics of disturbances which should be reported in catalog lists of disturbances, etc.

It is known that substantial changes in the ionosphere are frequently observed during violent magnetic storms, and for this reason research on ionospheric disturbances up to the present time involved mainly an examination of the condition of the ionosphere during magnetic storms.

However, the mean statistical characteristics of ionospheric conditions during magnetic disturbances, obtained up to the present time, differ to a very great extent from the characteristics of individual ionospheric disturbances and are almost not used at all for practical purposes. This is mainly due to the fact that various types of ionospheric disturbances occur at medium latitudes, so that a general averaging of these disturbances may even yield a quiet condition of the ionosphere. Until recently, this fact was not taken into account during the study of the morphology of ionospheric disturbances. In addition, a seasonal correction of the deviations of f_oF-2 during disturbances was not taken into consideration in the great majority of studies. The magnitude of this correction is shown in the present study.

By equating ionospheric and magnetic disturbances, and then averaging various ionospheric parameters during the course of magnetic storms, many authors also fail to take into account the well-known fact encountered in observations, namely that magnetic and ionospheric disturbances do not always start and take place simultaneously.

For these reasons, we believed that, in order to establish the average laws governing the course of ionospheric disturbances, it is necessary to establish their periods directly according to ionospheric disturbance characteristics, regardless of whether magnetic disturbances were or were not observed at the same time. The above statement, however, does not by any means exclude the belief that a study of ionospheric disturbances should be closely coordinated with a study of magnetic storms, aurora polaris and solar activity.

The present study gives the results obtained in an investigation of the morphology of ionospheric disturbances at medium latitudes, based on observations conducted at 5 ionospheric stations in the USSR (Figure 1) during years close to the maximum (1948 and 1949) and to the minimum (1952 and 1953) values of solar activity. Periods of ionospheric disturbances were selected directly on the basis of ionospheric data. Over 150,000 hourly values of f_0F-2 were used.

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List and Location of Ionospheric Stations Whose Observations Were Used in the Present Study

No	Station	Coordinates			
		Geographic		Geomagnetic	
		φ	λ	Φ	Λ
1	Leningrad	60.0° N	30.7° E	56.0° N	117.0° E
2	Moscow	55.5	37.3	52.0	120.3
3	Sverdlovsk	56.7	61.1	48.8	140.7
4	Irkutsk	52.5	104.0	41.0	174.4
5	Alma-Ata	43.2	76.9	33.0	150.5

The Problem of Criteria of Ionospheric Disturbance

In medium latitudes, deviations of f_0F-2 and $h'F$-2 from their normal values constitute the main symptom of ionospheric disturbances; for this reason, the following expression is considered as the main criterion of an ionospheric disturbance:

$$\Delta_{\text{dis}}\, f_0F2\% = \frac{f_0F2 - f_0F2_{\text{norm}}}{f_0F2\text{norm}} \cdot 100,$$

where f_0F-2 is the critical frequency during a given hour in megacycles (mc); and $f_0F\text{-}2_{\text{norm}}$ is the normal critical frequency along a sliding median (for each day), calculated over a period of 30 days for the same hour, in mc.

The use of a sliding median during the calculation of Δdis.f_0F-2 excludes errors due to the seasonal course of f_0F-2, which are particularly great during years of maximum solar activity, and which not only are comparable in size with deviations caused by disturbances, but which may even exceed these deviations during certain hours of the day. For example, during spring, summer and fall, the morning and evening seasonal deviations of f_0F-2 may amount to $\pm$ 30% of the normal non-sliding median (Figure 2, at points where the curves are intersected by the straight lines A and B). When the seasonal course of f_0F-2 is not taken into account, not only will seasonal deviations be erroneously considered as disturbances, but even the other way round, considerable disturbances will remain undetected since they will be masked by seasonal deviations of the stream running in an opposite direction.

F49 The value of Δ dis.f_0F-2 should preferably be expressed in relative units, and not in megacycles, since it is practically impossible to set up such a single measure in megacycles which could serve as a disturbance index during any time of the day, year and period of solar activity even for a single station. At the same time, the absolute values of Δdis.f_0F-2 are unequal.

Methods Used in Identifying Disturbance Periods. Types of Ionospheric Disturbances in the F-2 Region.

Tables showing hourly values of Δ dis.f_0F2 during 4 years at 5 stations were drawn up. When Δ dis.f_0F2 did not exceed 20%, we arbitrarily considered the ionosphere to be quiet. When Δ dis.f_0F2 exceeded $\pm$ 20%, and this was observed for a long period of time, equal to at least 5 hours, we considered that a ionospheric disturbance was taking place.

In addition to a quantitative criterion, i.e., Δdis.f_0F2, the following qualitative indices showing the condition of the ionosphere were also taken into account during the identification of disturbance periods: absorption, strong diffusivity, appearance of the Es layer during hours when this layer is usually absent, the shielding of the F2 layer by the F-1 layer, and the appearance of the F-1 layer at an unusual time, for example at night.

Regardless of the period of solar activity, the ionospheric disturbances occurring at medium latitudes are either negative (D-), when the critical frequencies of the F2 layer have mostly below-normal values during the course of the entire disturbance; or positive (D+), when the values of f_0F2 are mostly above normal during the course of the entire disturbance. Occasionally, the disturbances have a two-phase character (D+-), when prior to a drop of f_0F2, i.e., prior to the negative phase, a positive phase is observed during the course of several, usually small number of hours. Very rarely are mixed disturbances (D_{mix}) observed, when periods of positive and negative deviations of f_0F2 alternate in a most varied sequence. The distribution of storms (in percent), according to types occurring in a 40-60° North latitude zone, is shown in Table 1.

Table 1

Type of Storm	Great and Moderate Storms		Small Storms	
	Ss-max	Ss-min	Ss-max	Ss-min
D-	61	50	45	29
D+	18	33	45	56
D+-	17	12	5	9
D_{mix}	4	5	5	6

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Note: Ss-max: Years of maximum occurrence of sun spots;
Ss-min: Years of minimum occurrence of sun spots.

The identified storms were listed in a catalog, which contained the following information: the date on which the disturbances occurred, and the time of their onset and end; the type of disturbance and its duration in hours; the maximum value of Δdis.f_0F2 in percent, with an indication of the deviation sign; the average value of Δ dis.f_0F2 during the entire disturbance period; the time of onset and end of the active periods of a given disturbance; characteristic of this disturbance (number of active hours divided by the number of hours of the entire disturbance); the category of the disturbance (very great, great, moderate, small).

"Prohibited" Time for the Onset of Ionospheric Disturbances in the F-2 Region

The "prohibited" time during a 24-hour period (i.e., the time at which the onset of any type of ionospheric disturbance may not take place) was established by studying tables listing hourly values of Δdis.f_0F2. The stability of the F-2 layer in regard to the onset of disturbances and the duration of "prohibited" periods are determined primarily by the following two factors: the altitude of the sun above the horizon, and the actual structure of the F-2 layer. If the F region is subject to a stratification process involving the formation of 2 layers, F-1 and F-2, the F-2 layer becomes unstable and the onset of disturbances can easily take place in this layer. The probability that a great or moderate ionospheric disturbance cannot start during a period of "prohibited" time for the onset of disturbances is very great, and is almost equal to 100% (Tables 2 and 3).

Table 2

Probability That A Negative Ionospheric Disturbance Will Not Start During A Period of "Prohibited" Time (In A 24-Hour Day) for the Onset of Disturbances

Season	Station	"Prohibited Time (Belt), hours		Probability, %	
		From	To	Ss-max	Ss-min
Winter (January, February, November, December)	Leningrad	6	16	100	100
	Sverdlovsk	7	17	100	100
	Moscow	6	17	100	100
	Irkutsk	6	17	99.96	99.96
	Alma-Ata	6	18	100	100
Equinox (March, April, September October)	Leningrad	7	Sunset	99.96	99.96
	Sverdlovsk	9	"	100	100
	Moscow	8	"	100	99.96
	Irkutsk	8	"	100	99.92
	Alma-Ata	7	"	100	100
Summer (May, June, July, August)	Leningrad	8	1 hour prior to sunset	100	100
	Sverdlovsk	10	Sunset	99.96	99.96
	Moscow	8	1 hour prior to sunset	99.96	99.96
	Irkutsk	8	Sunset	100	99.96
	Alma-Ata	8	1 hour prior	99.97	99.97

Table 3

Probability That A Positive Ionospheric Disturbance Will Not Start During A Period of "Prohibited" Time (In A 24-Hour Day) for the Onset of Disturbances

Season	Station	"Prohibited Time (Belt), hours		Probability, %	
		From	To	Ss-max	Ss-min
Winter (January, February, November, December)	Leningrad	8	Sunset	100	100
	Sverdlovsk	8	"	100	99.95
	Moscow	7	"	100	100
	Irkutsk	8	"	99.95	99.95
	Alma-Ata	6	"	100	100
Equinox (March, April, September October)	Leningrad	8	Sunset	100	100
	Sverdlovsk	8	"	100	100
	Moscow	6	"	100	100
	Irkutsk	6	"	100	100
	Alma-Ata	5	"	100	100
Summer (May, June, July, August)	Leningrad	4	Sunset	100	100
	Sverdlovsk	6	"	100	99.97
	Moscow	5	"	100	100
	Irkutsk	5	"	100	100
	Alma-Ata	4	"	100	100

The graphs showing the duration of "prohibited" periods in relation to the season and the geographic latitude for a belt of 40-60° N latitude (Figures 3 and 4) can be used during the short-term forecasting (prognosis) of ionospheric conditions. If, at the beginning of the "prohibited" period, which is determined from the graph, there is no ionospheric disturbance in the F-2 layer, one can assume with a practically 100% probability that no great or moderate disturbance will occur until the end of the "prohibited" period, and radio communication operations can be safely planned during this period, as is usually done during normal ionospheric conditions.

The fact that ionospheric disturbances in the F-2 region cannot start at any time of a 24-hour day will possibly provide a satisfactory explanation for the non-simultaneous occurrence of the onset of ionospheric and magnetic disturbances in the F-2 layer, as well as for the non-simultaneous onset of ionospheric disturbances at different stations, particularly at stations located at remote latitudes.

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Diurnal Course of Disturbances

For practical purposes, it is most important, in our opinion to know the diurnal intensity course of disturbances, i.e., the magnitude of $\triangle$ dis.f_oF2, as well as the diurnal course of the probability of disturbance hours.

As a result of a detailed study of the diurnal course of $\triangle$ dis.f_oF2 values and of the number of active hours in storms (A factor), it was possible to draw graphs showing the diurnal course of $\triangle$ dis.f_oF2 in the 40-60° N latitude zone, depending upon the type of storm, the solar activity period and the time of the year (Figure 5). These charts (graphs) can also be used for practical purposes of radio communications during ionospheric storms.

On the basis of a comparison between the actual diurnal courses of $\triangle$dis.f_oF2 during the active periods of individual storms and the diurnal course derived from the chart shown in Figure 5, it is possible to conclude that these courses coincide fairly well.

Practical conclusions in regard to the diurnal intensity course of negative disturbances and the probable occurrence of their active hours are given in Tables 4 and 5.

Table 4

Most Favorable Periods for Radio Communication Operations During D-Type Disturbances in A 40-60° North Latitude Zone

Period	Season	Local Time in the Wave Reflection (Hop) Region (Most Favorable Periods), hours		Probability of Non-Active Disturbance Periods,%	Mean Deviation of f_oF2 From Normal Values, %	Mean Deviation of f_oF2 in Case of Active Periods,%
		From	To			
Years of maximum sun spot occurrence	Winter	8	16	80	-10	-40
	Equinox	13	20	60	-15 -20	-30
	Summer	15	21	40	-20	-25
Years of minimum sun spot occurrence	Winter	8	16	80	-10	-25
	Equinox	13	20	60	-12 -15	-25
	Summer	12	21	75	-12	-22

Table 5

Most Difficult Periods for Radio Communication Operations During D-Type Disturbances in a 40-60° North Latitude Zone (In case of maximum $\triangle$dis.f_oF2 values and maximum probability of active hours during disturbances).

Period	Season	Local Time in Wave Reflection (Hop) Region (Most Difficult Periods), hours		Probability of Active Disturbance Periods,%	Mean Deviation of f_oF2 During Active Disturbance Periods, %
		From	To		
Years of maximum sun spot occurrence	Winter	20	6	0.6	-30
	Equinox	23	11	0.7	-25 -32
	Summer	22	13	0.85	-30
Years of minimum sun spot occurrence	Winter	20	6	0.6	-25
	Equinox	23	11	0.6	-22 -27
	Summer	22	4	0.65	-25 -30

D_{st} - Variation

The D_{st}($\triangle$dis.f_oF2) - variation was determined in order to clarify the problem as to how the intensity of a ionospheric disturbance changes according to the time elapsed since the onset of the disturbance.

For practical purposes, it is indispensable to clarify the nature of this relationship, in order to know on which day or at what hour the storm may be expected to reach its greatest intensity. The period of each storm was taken as the unity.

For all types of disturbances, a common characteristic feature and peculiarity of the D_{st} - variations obtained is the extremely small variation of the mean hourly $\triangle$ dis.f_oF2 values from the onset and up to the end of the disturbance. A regular change in the intensity of the ionospheric disturbance, in relation to the time elapsing from the beginning of the disturbance, practically does not take place.

The onset of an ionospheric storm and the return of the ionosphere to a normal condition, as shown in Figure 6, take place practically at once, without a gradual and slow decline or rise of frequencies. This fact indicates that individual ionospheric storms may reach a highest intensity in any portion of the storm period.

Consequently, when forecasting critical frequencies for a period of ionospheric disturbances, it is sufficient to consider only the diurnal course of Δdis.f_oF2 corresponding to a specific season, solar activity year or latitude, and it is not necessary to consider changes of Δdis.f_oF2 in relation to the time of the storm. For this reason, it is not necessary to calculate the diurnal course of Δdis.f_oF2 separately for the first, second, third and subsequent days of the storm.

The seasonal and latitudinal change of the D_{st}-variation consists merely in a change of the magnitude of D_m.

Conclusion

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The conclusions reached in the present study concerning the morphology of ionospheric disturbances differ substantially from the conclusions published in special articles. The reason for this difference does not lie in the more careful calculations and in the greater number of original data, but is rather due to the fact that, prior to the beginning of statistical calculations of mean characteristics, the storms were at first divided and grouped according to definite types (D-, D+, D+-, D_{mix}); second seasonal deviations were taken into account during the calculation of critical frequency deviations during disturbances; and third, the presence of ionospheric disturbances was established directly on the basis of ionospheric data. The obtained results were confirmed by comparison with actual changes in the critical frequencies of the F-2 layer during the course of disturbances.

The morphology of ionospheric disturbances was examined in the present study mainly in order to allow the use of the conclusions derived from this study in practical radio communication operations, and to allow the forecasting of ionospheric conditions during the course of disturbances.

As a result of the conclusions reached in this study, the following suggestions are made:

1. In studying the mean characteristics of the course of ionospheric disturbances, we suggest that:

a. Disturbance periods should be identified on the basis of ionospheric data, without equating automatically ionospheric and magnetic storms.

b. Prior to starting statistical computations, storms should be divided and grouped according to types, and the establishment of mean characteristics derived by simultaneous averaging of negative and positive storms should not be allowed.

c. Deviations of f_oF2, expressed in relative units or in per-cent of a sliding median, should be considered as the basic quantitative criterion of ionospheric disturbance at medium latitudes; the use of a sliding median is required in view of the necessity of taking the seasonal course of f_oF2 into account.

d. In drawing up a log of ionospheric storms, the following data should be listed: the date, and the time of onset and end, of the disturbance; the duration of the disturbance in hours; the maximum value of Δdis.f_oF2; the average value of Δ dis.f_oF2 during the course of the storm; the time of onset and end of active periods; a description of the disturbance; and the category of the disturbance (very great, great, moderate, small).

2. To recommend the use of charts showing the "prohibited" time of the day (24-hour period) for the onset of storms (see Figures 2 and 3) and the use of tables listing the most favorable and the most difficult hours of operation during storms (see Tables 4 and 5), used for practical radio communication purposes, in particular during the short-term fore-casting of ionospheric conditions in medium latitudes.

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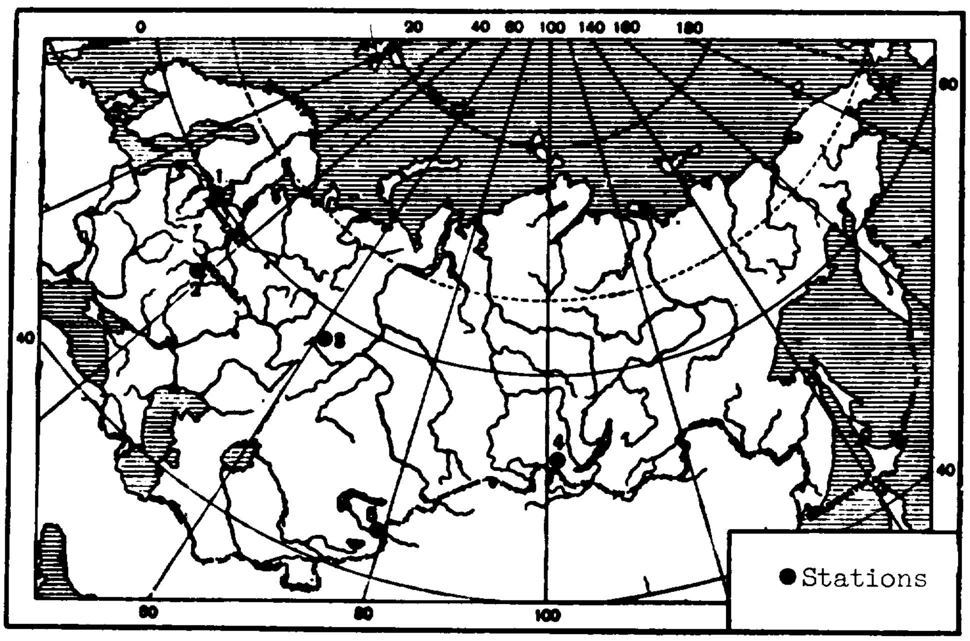

Figure 1.- Location of ionospheric stations whose observations were used in the present study.

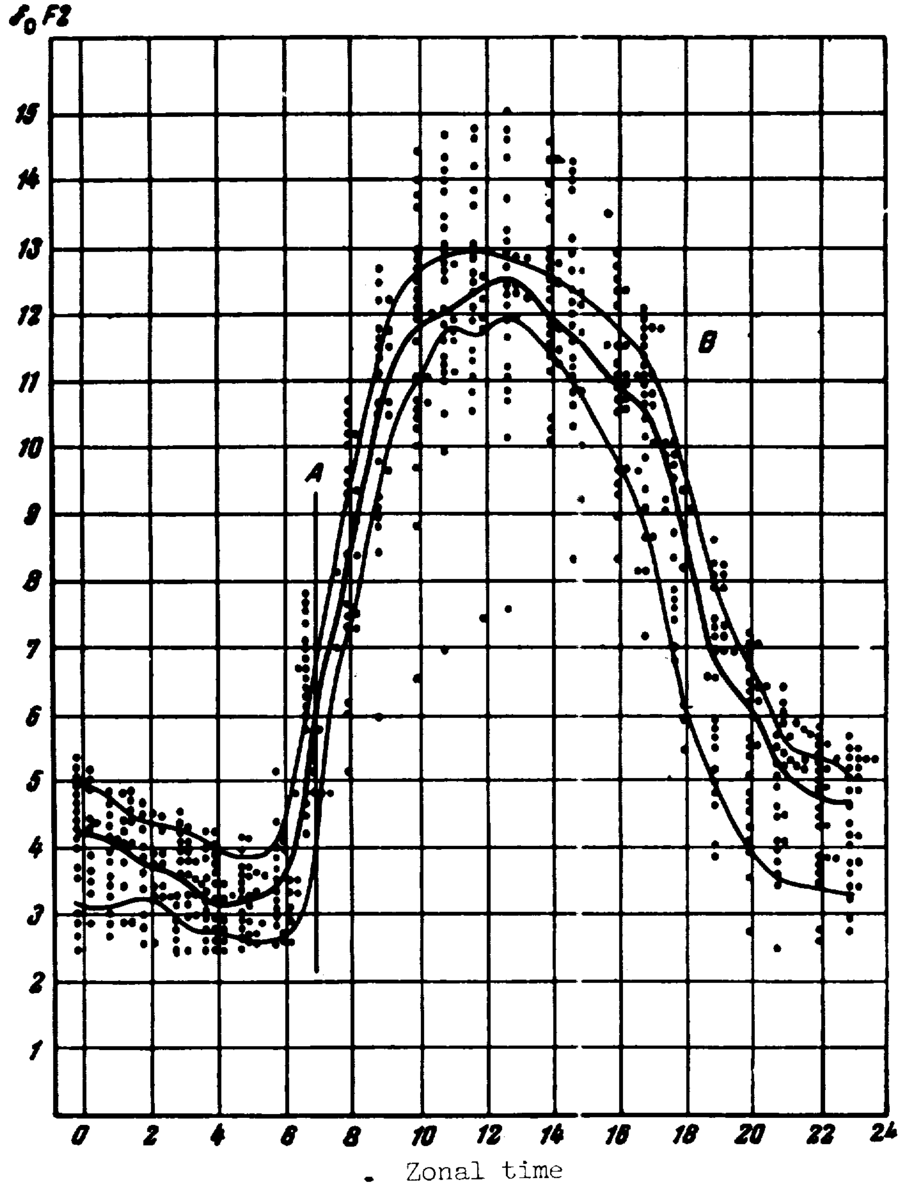

Figure 2.- Monthly median for February 1 (lower curve), February 15 (middle curve) and February 28 (upper curve) 1949 (Moscow).

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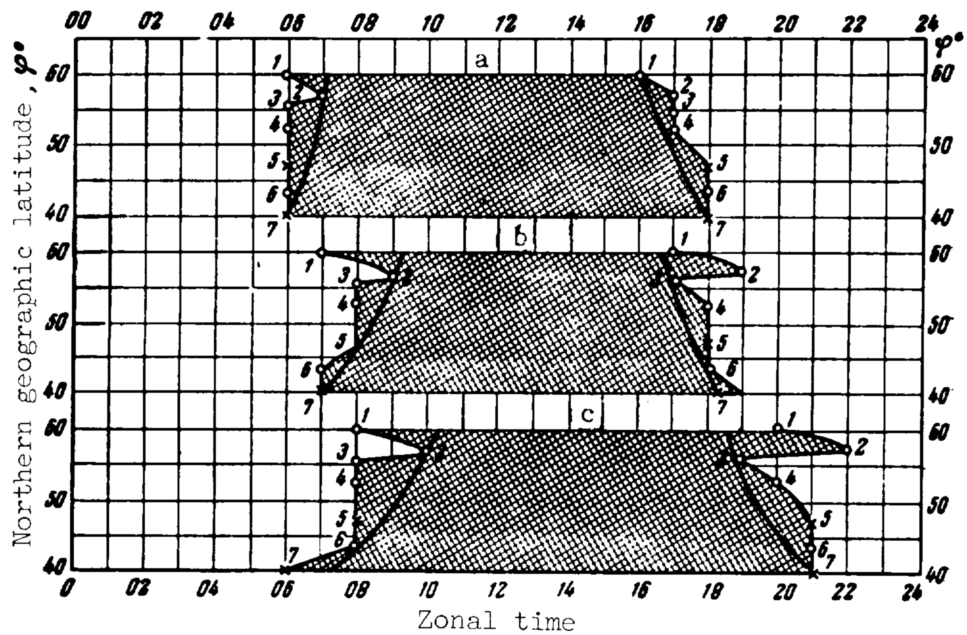


Figure 3.- "Prohibited" time for the onset of negative disturbances (shaded area), according to seasons, for the 40-60° north-latitude zone. a - winter; b - equinox; c - summer. 1 - Leningrad; 2 - Sverdlovsk; 3 - Moscow; 4 - Irkutsk; 5 - Poitiers (France); 6 - Alma-Ata; 7 - Washington (USA).

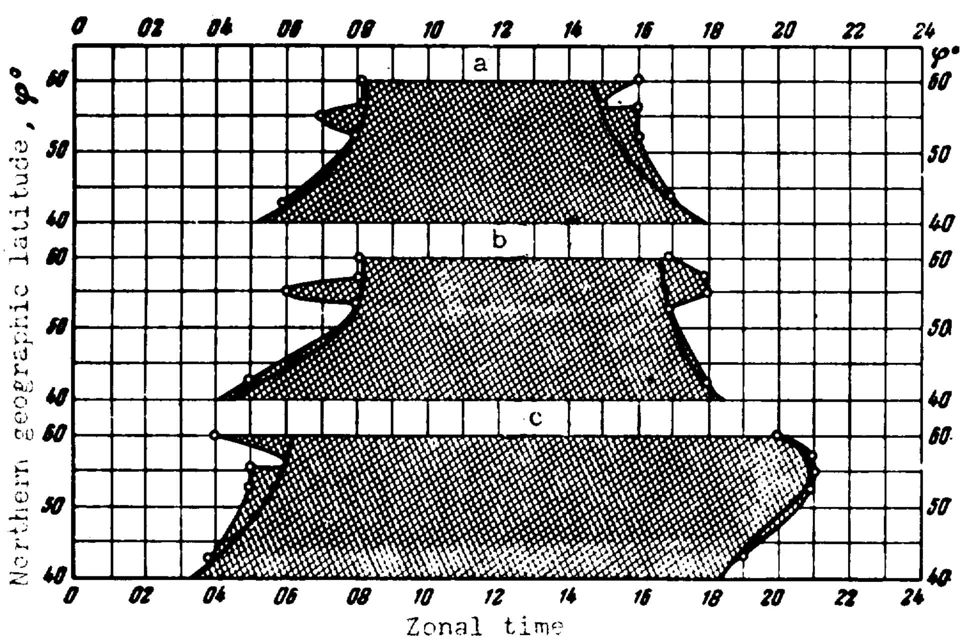
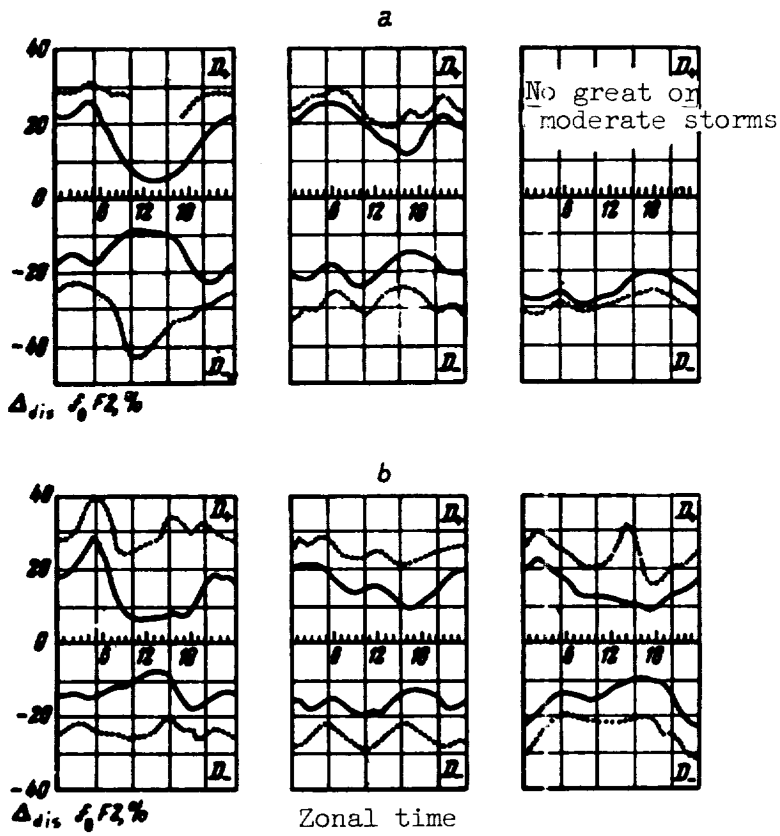


Figure 4.- "Prohibited" time for the onset of positive disturbances (shaded area), according to seasons, in the 40-60° north-latitude zone.



a - Maximum sun spot occurrence (1948 and 1949).
b - Minimum sun spot occurrence (1952 and 1953).

Figure 5.- Diurnal intensity course of great and moderate ionospheric storms in the 40-60° north-latitude zone. Negative storms are plotted under the abscissa, and positive storms above the abscissa. The solid line shows the diurnal course corresponding to each hour of the storm; broken lines indicate the course corresponding to the active hours of the storm.

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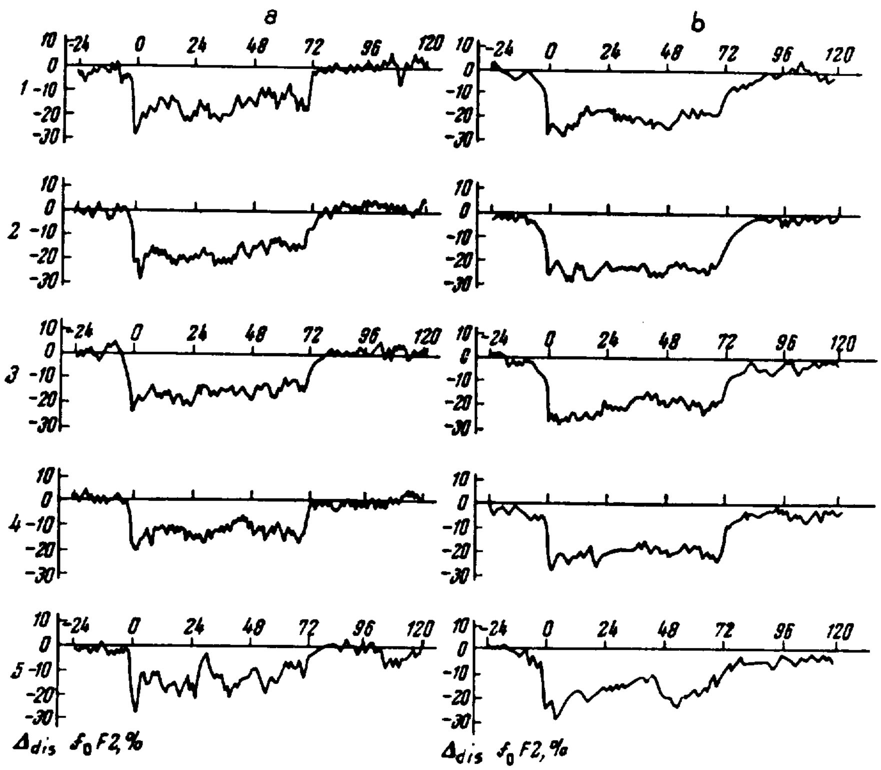

a - Minimum sun spot occurrence (1952 and 1953).
b - Maximum sun spot occurrence (1948 and 1949).

1 - Leningrad; 2 - Moscow; 3 - Sverdlovsk; 4 - Irkutsk; 5 - Alma-Ata.

Figure 6.- $D_{st}(\Delta_{dis} f_0 F2)$ - variations of great and moderate negative ionospheric storms (D-).

Connection Between Ionospheric and Magnetic Disturbances at High Latitudes (see Note)

By R. A. Zevakina

A number of researchers (1-7) have discovered that magnetic disturbances at high latitudes are accompanied by an increase in the ionization density of the Es layer, a considerably higher absorption of radio waves, and also by great changes in the critical frequencies and altitudes of the F-2 layer. However, the morphology of ionospheric disturbances is still not quite clear at the present time, and the types of changes in the ionosphere which accompany various types of geomagnetic disturbances have not been determined. F49

The present study examines abnormal changes in the ionosphere occurring during magnetic storms and bay-like disturbances of the geomagnetic field, based on observations conducted at Murmansk in 1954-1957. The following factors were considered as criteria of a disturbed condition in the ionosphere: the appearance of a total (B) or increased absorption, characterized by the presence of high absorption values; f-min (see Note) (f-min $\geqslant$ 3 mc); an increase in critical frequencies of the E layer (fEs $\geqslant$ 4 mc), and considerable deviations of f_oF2 from medians ($|\Delta fF2| > 20\%$). Such phenomena, if observed during the course of 5 hours or longer, were considered as ionospheric disturbances (storms). On the basis of the above symptoms, a total of 365 ionospheric storms was observed during 1954-1957. (Note: The ionospheric station always operated at maximum amplification. The lower limit of the equipment was equal to 1.5 mc in 1954-1955, and 1.0 mc in 1956-57).

Ionospheric and Magnetic Storms

Great and moderate ionospheric storms were usually accompanied by magnetic storms. However, a substantial difference, amounting to as much as 20 hours, was observed in the time of onset and end of such storms. Let us assume that in 50% of the cases ionospheric storms started earlier, and in 50% of the cases, later than magnetic storms. In most cases, ionospheric storms lasted for a longer time than magnetic storms. A relation to the time of the day (24-hour period) was observed in the onset and termination of the storms. Most ionospheric and magnetic storms started during the period from 16 to 24 hours, and ended during the period of 24 to 8 hours, according to zonal time.

(Note: Based on data obtained at the Murmansk Section of the Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation of the Academy of Sciences USSR).

The nature of ionospheric changes occurring during storms varies greatly. Figure 1 shows the frequencies of occurrence (P) fEs $\geqslant$ 4 mc, of the shielding Es (A) layer, of total absorption, of f-min $\geqslant$ 3 mc, of $|\Delta f_oF2| > 20\%$, and mean values of Δf_oF2 during moderate, great and very great storms, as well as during quiet periods, 1 day prior to the storm, 1 day after the storm, during midnight hours (23, 00 and 01 hours), and during noon hours (11, 12, 13 hours). An examination of Figure 1 and of the results of a similar analysis of small storms shows that Es with high critical frequencies and a total absorption were most frequently observed during large and small storms. Among the small number of abnormal Δf_oF2 which were observed, positive deviations were observed somewhat more frequently at night, while negative deviations were observed during the day. Mean values of Δf_oF2 were somewhat higher during night time disturbances, and were lower during daytime, than during quiet periods. The nature of abnormal changes in the ionosphere varies according to the time of the day (24-hour period). This can be clearly seen in Figure 2, which shows the diurnal variations of the frequencies of occurrence of total absorption, f-min $\geqslant$ 3 mc, fEs $\geqslant$ 4 mc, and of positive and negative ΔfF2 $>$ 20%. An examination of this figure shows that total absorption was most frequently observed during morning hours (4-8 o'clock). A higher rate of absorption, characterized by a high f-min value, was observed during mid-day hours (8-16 o'clock). A maximum P value (fEs $\geqslant$ 4 mc) occurred during midnight hours. Values of $|\Delta f_oF2| > 20\%$ were observed somewhat more frequently during evening hours.

Hourly amplitudes of the horizontal component of the geomagnetic field (r_H) were used as a characteristic of magnetic disturbance. The diurnal course of r_H reveals the presence of 3 maxima (peaks) at 20-22, 2-3 and 14-17 hours (Figure 3). The morning peak is more sharply expressed during the summer months. The diurnal course of r_H is very similar to the diurnal course of P (fEs $\geqslant$ 4 mc), shown in Figure 2. In case of high fEs values, active periods of magnetic storms were generally observed.

Similar changes in the ionosphere during disturbances were also observed at other high-latitude stations. We have examined data corresponding to several disturbed periods in 1954 (16-25 January, 10-20 April, 4-14 July and 7-17 September), obtained at the following stations: Tikhaya Bay (80°20' N, 52°48' E), Tiksi Bay (71°33' N, 128°54' E) and Murmansk (68°58' N, 33°05' E). In Murmansk and Tiksi Bay, high fEs values were observed during these periods at night, and total absorption was observed during daytime hours. At Tikhaya Bay, high fEs values were more frequently observed during daytime and night hours than total absorption. Observations of the F-2 layer were seldom conducted during these periods at all 3 stations.

The frequency of occurrence of these particular elements in a disturbed state of the ionosphere varies considerably according to the time of the year (Figure 4). Total absorption is most frequently observed during equinox periods, while a higher absorption rate is observed during equinox periods and in the summer; values of fEs $\geq$ 4 mc at night were observed more frequently in winter, while similar values during daytime were usually observed in summer (the time extending from 19 to 6 hours is considered as night time during the course of the whole year). Values of $|\Delta\ f_oF2| > 20\%$ were observed somewhat more frequently in the winter. The highest rate of activity of magnetic disturbances was observed during equinox periods (Figure 3). An examination of Figure 4 shows that the seasonal course of the disturbance factors examined here varies somewhat with the increase in solar activity from 1954 to 1957.

Changes in the Ionosphere During Bay-Like Magnetic Disturbances

The following analysis was conducted in order to determine the nature of ionospheric changes occurring during magnetic bay-like disturbances. Changes in the values of fEs, f-min and $\Delta\ f_oF2$ were examined during the course of each bay, observed at Murmansk from 1954 to 1957, and also for 2 hours prior to the onset of the bay and for 2 hours following its termination. Bay-like disturbances included disturbances lasting for less than 5 hours and having an amplitude greater than 30 gamma, observed in connection with a quiet or weakly disturbed magnetic field prior to the appearance of bays and after their termination. A total of 504 bays were examined, including 287 negative and 207 positive bays. Negative bays were mostly observed between 21 and 5 hours, while positive bays were observed from 12 to 21 hours zonal time. During the course of the year, negative bays were mostly observed during the summer, while positive bays were observed in the winter. F 4 9

During bay-like disturbances, the same abnormal changes in the ionosphere occurred as in magnetic storms: an increase in both fEs and f-min values was noted, or a total absorption took place. Sometimes, significant changes in the values of f_oF2 were noted. However, fEs values during bays were lower than during storms. For this reason, an increase of fEs above 3 mc during bays was considered as an abnormal change in the ionosphere. Figure 5 shows changes in the frequencies of occurrence of fEs $>$ 3 mc, in total absorption, in f-min $\geq$ 3 mc and in $|\Delta\ f_oF2| > 20\%$ occurring during bays and control hours (2 hours prior to the onset and 2 hours after the termination of the bays). An examination of this figure shows that the frequency of occurrence of P cases when fEs $>$ 3 mc and of total absorption is considerably greater during positive and negative bays than during control hours. The highest values of P(B) and P(fEs $>$ 3 mc) occur during the second and third hour following the onset of the bays, i.e., at a time when the bay amplitudes reach a maximum value. P($|\Delta\ f_oF2| > 20\%$) are higher during bays than during control hours in 1956, P(f-min $\geq$ 3 mc) - in 1956 and 1957. In addition to quantitative changes in ionospheric characteristics, qualitative changes also took place both during bays and storms, which were expressed in the form of diffuse reflections from the Es and F-2 regions.

The following table lists the number of positive and negative bays (in percent), marked by the appearance of fEs $>$ 3 mc, total absorption, values of f-min $\geq$ 3 mc, and a deviation of f_0F2 from medians exceeding 20%. If one of these phenomena was observed at least once during the bay, it was assumed that an abnormal change of the ionosphere was taking place (ionospheric measurements were performed once an hour).

Table

Nature of abnormal changes in the ionosphere	Type of bay	Number of bays accompanied by abnormal changes, in %				
		1954	1955	1956	1957	1954-1957
Any type of abnormal change in the ionosphere	Negative	87	88	80	88	87
	Positive	70	73	76	85	81
fEs $>$ 3 mc	Negative	80	53	60	67	66
	Positive	38	42	31	54	42
Total absorption	Negative	18	30	26	25	25
	Positive	30	25	10	3	18
f-min $>$ 3 mc	Negative	0	2	13	18	8
	Positive	6	6	7	25	11
$\lvert \Delta f_0F2 \rvert >$ 20%	Negative	12	20	35	27	23
	Positive	8	25	38	22	21

An examination of the above table shows that 87% of the negative bays and 81% of the positive bays were accompanied by abnormal changes in the ionosphere. An increase of fEs above 3 mc was observed in 66% of the negative bays and in 42% of the positive bays. Total absorption occurred in 25% of the negative and in 18% of the positive bays, while a higher rate of absorption was observed in 8% of the negative and in 11% of the positive bays. Deviations of fF2 from medians, exceeding 20% were observed in 23% of the negative and in 21% of the positive bays.

Thus, during negative and positive bays, as well as during storms, higher critical frequencies in the Es layer were most frequently observed, while abnormal changes of f_oF2 were rarely observed. All abnormal changes in the ionosphere were observed more frequently during negative bays, rather than during positive bays.

Conclusion

The high degree of coincidence between abnormal changes in the ionosphere and magnetic disturbances indicates that magnetic disturbances at high latitudes are caused by processes arising and evolving in the ionosphere during the intrusion of particles mainly at an altitude of 100 km. Magnetic disturbances, apparently, arise as a result of a great disruption and change in the system of currents, responsible for quiet daily variations.

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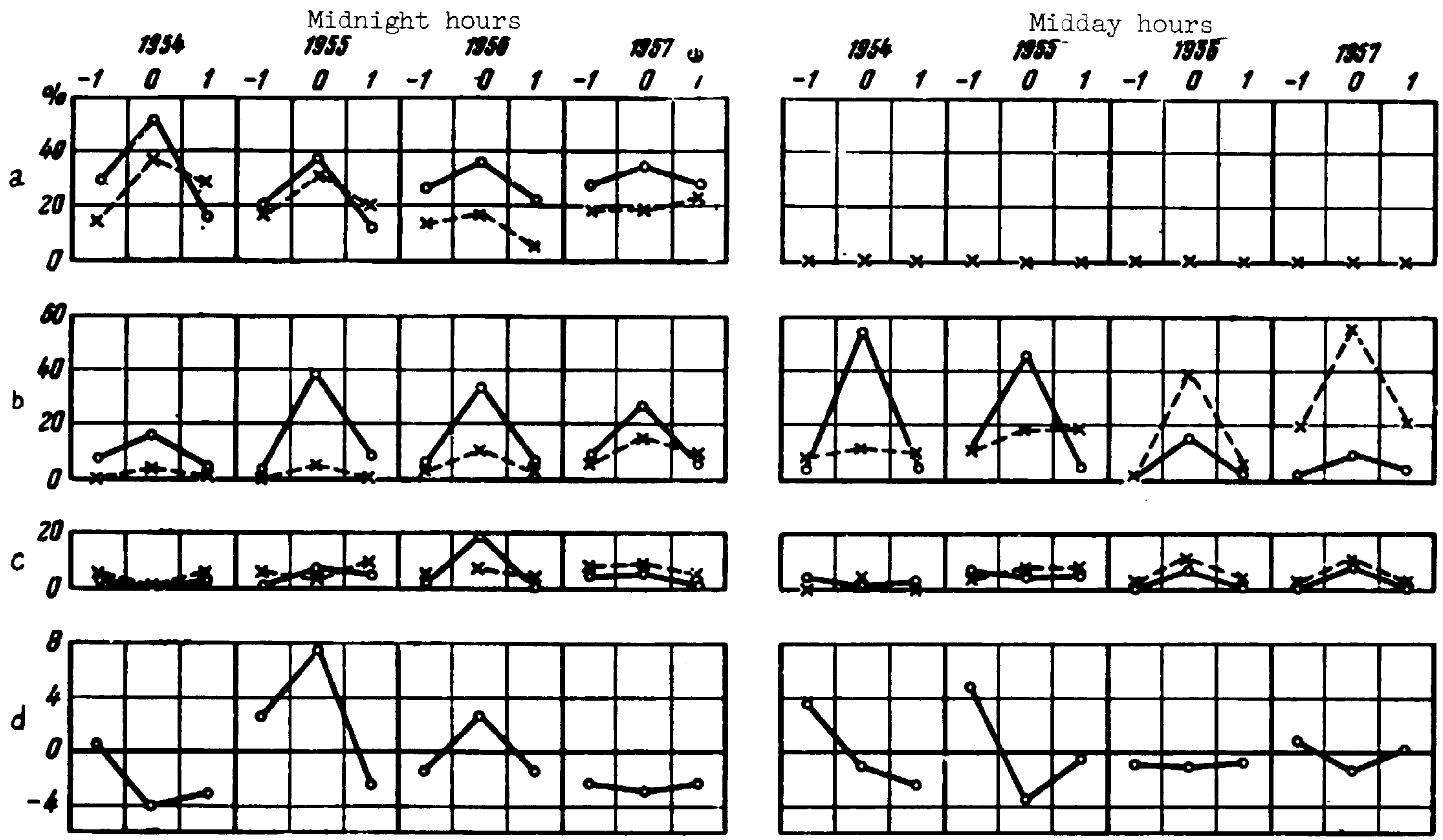
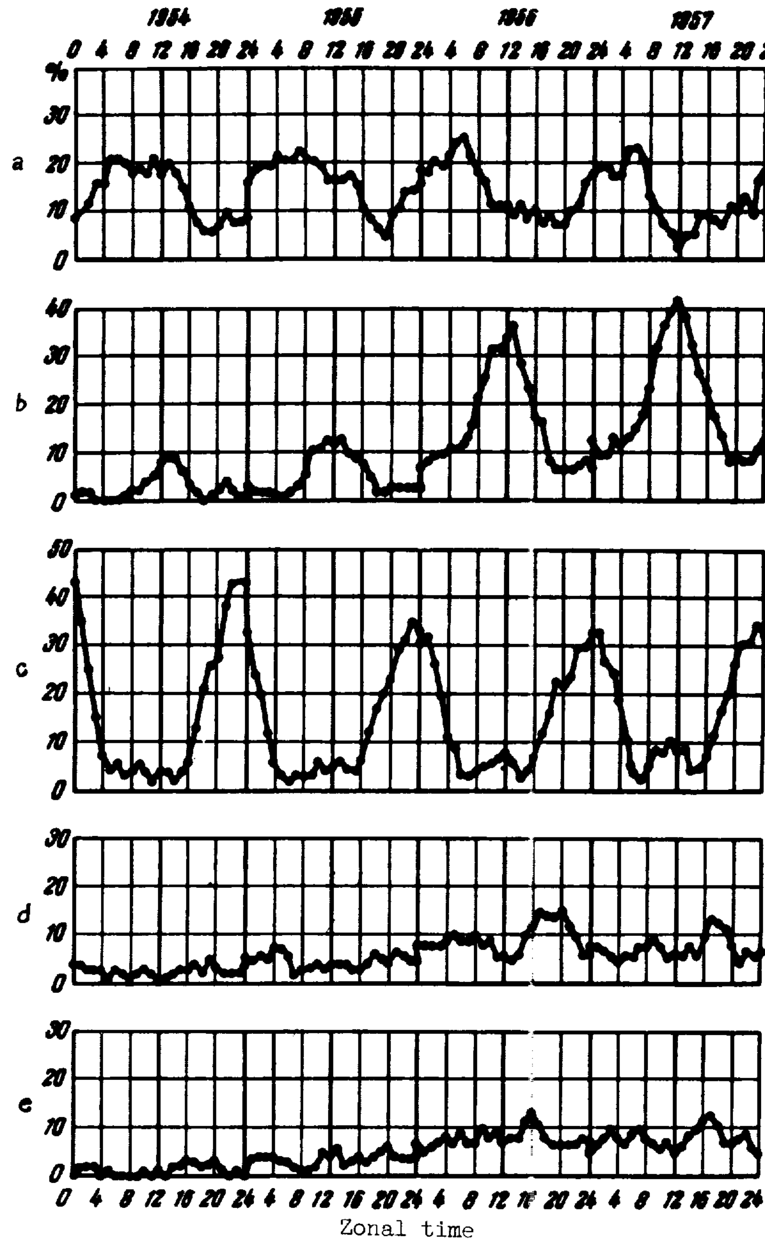


(a) P(fEs ≧ 4 mc) - solid line, P(A) - broken line. (b) P(B) - solid line, P(f-min ≧ 3 mc) - broken line. (c) $P(\Delta f_0F2 > 20\%)$ - solid line, $P(-\Delta f_0F2 > 20\%)$ - broken line. (d) Mean values of Δf_0F2.

Figure 1.- Frequency of occurrence of abnormal changes in the ionospere during moderate and large storms and on quiet days, measured 1 day prior to the storm and after the storm at the same hours (Murmansk).



(a) P(B).

(b) P(f-min ≥ 3mc).

(c) P(fEs ≥ 4mc).

(d) $P(\Delta f_0F2 > 20\%)$.

(e) $P(-\Delta f_0F2 > 20\%)$.

Figure 2.- Diurnal variations in the frequency of occurrence of total absorption (Murmansk).

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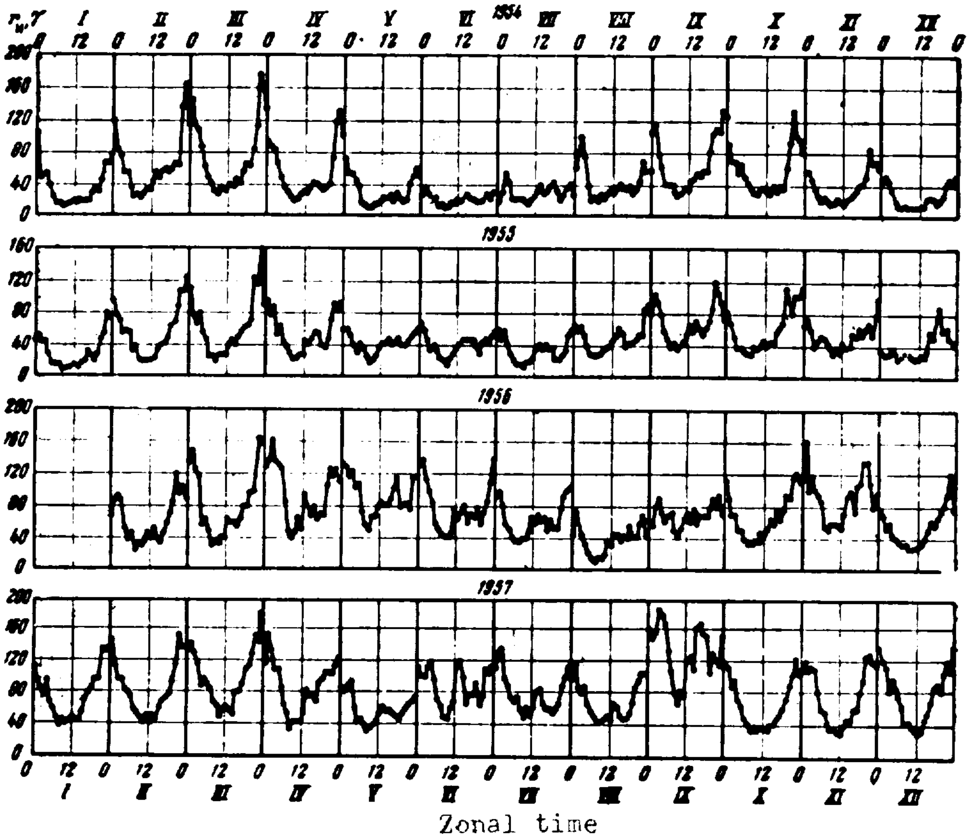
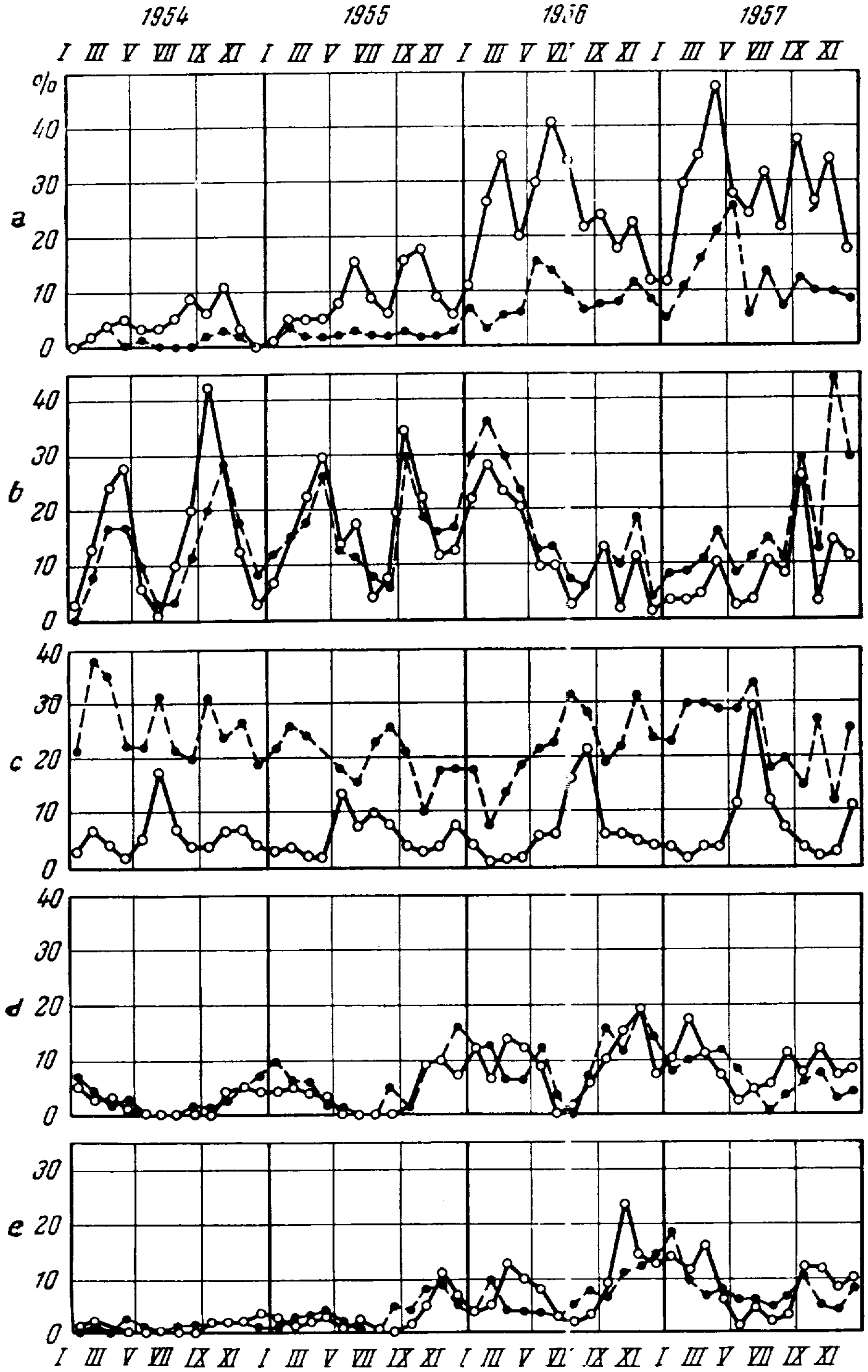


Figure 3.- Variations of average monthly hourly r_H values during the course of the day (24-hour period) and during the year at Murmansk. (Roman numeral I is for January, II is for February, etc.)



(a) P(f-min ≧ 3 mc)

(b) P(B)

(c) P(fEs ≧ 4 mc)

(d) P(Δf_0F2 > 20%)

(e) P($-\Delta f_0F2$ > 20%)

Figure 4.- Seasonal variations in the frequencies of occurrence. Solid line - daytime values; broken line - night-time values

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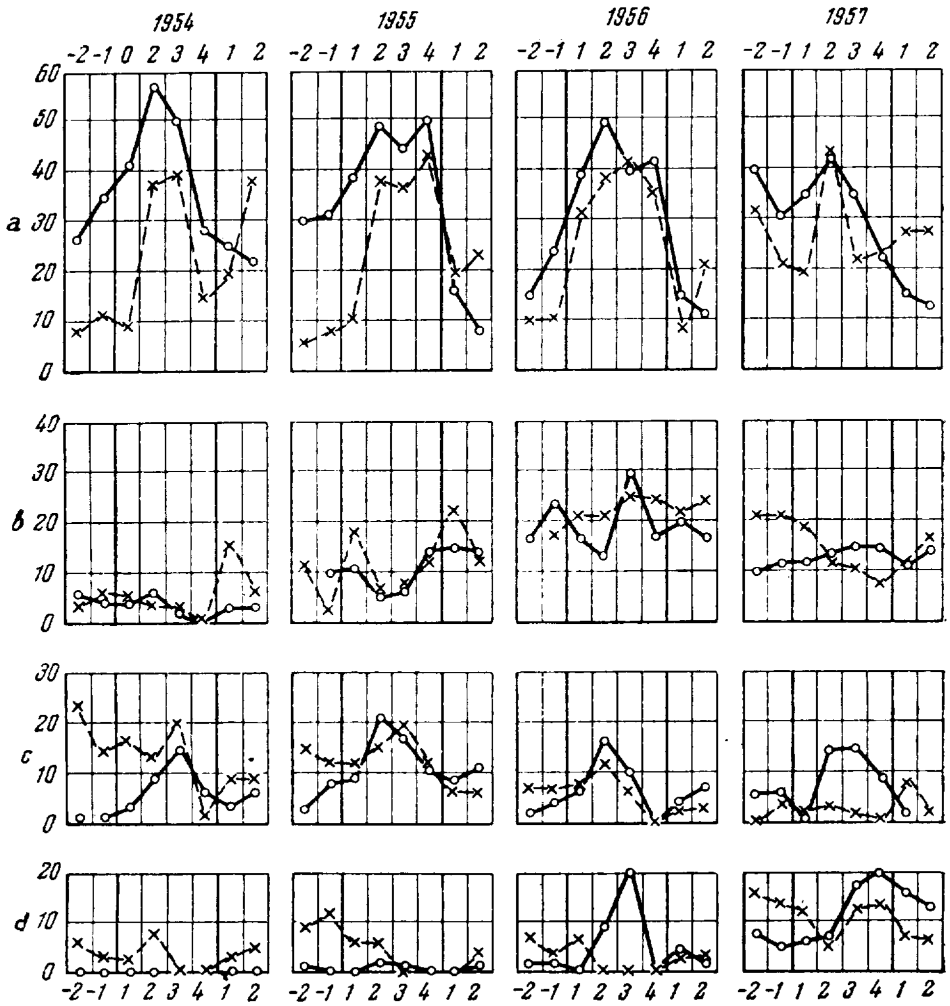

(a) P(fE > 3 mc)

(c) P(B)

(b) P(Δf_0F2 > 20%)

(d) P(f-min $\geqq$ 3 mc)

Figure 5.- Frequency of occurrence during bays and 2 hours prior to their onset and after their termination. Solid line - negative values; broken line - positive values.

Certain Types of Pulsations of the Geomagnetic Field and Earth Currents Occurring Simultaneously on the Territory of the USSR

By A. G. Kalashnikov

The phenomenon involving short-period pulsations of the geomagnetic field and earth currents, which is totally recorded at highly sensitive IGY stations, apparently consists of a superposition of various types of oscillations. The sources of these oscillations may be located in the upper atmosphere, in the ionosphere, in the earth crust and in deep portions of the earth. At each given moment of time, there is a region where these sources are predominantly found, although such sources may be present in other regions. F49

In order to determine the origin of individual types of short-period pulsations, it is most expedient to investigate those types of pulsations which are characterized by specific symptoms. The following basic symptoms were selected by us: simultaneous appearance of pulsations of the geomagnetic field and earth currents at different stations in the USSR: a completely identical shape of these pulsations; and a more or less identical period of fundamental oscillations. At the same time, the shape of pulsations in earth currents will, as a rule, be somewhat different than the shape of geomagnetic field pulsations. This is natural, since ΔH_z is recorded in case of the geomagnetic field, while in the case of earth currents, ΔE_x and ΔE_y are recorded, which, in view of their induction origin, are $H(t)$ time derivatives.

We have studied the recorded pulsations obtained at Soviet stations, and we have discovered a number of different types of such pulsations, which occur almost simultaneously on a territory extending from 39 to 160° East longitude and from 42 to 68° North latitude.

The following stations are located on this territory (Table 1)

Table 1

Station	Geographic coordinates		Geomagnetic coordinates	
	North Latitude	East Longitude	Latitude	Longitude
Borok	58°02'	38°58'	52°53'	123°20'
Lovozero	67 59	35 05	62 45	127 18
Petropavlovsk-Kamchatskiy	53 06	158 38	44 24	218 14
Simferopol'	44 50	34 04	41 12	113 18
Tbilisi	42 05	44 42	36 18	122 00

The scanning speed on recordings of the geomagnetic field and earth currents was equal to 90 mm/hr. With the aid of such scanning, the beginning and end of pulsations could be determined with an accuracy of up to 2 minutes.

During the course of August, September and November 1957, 9 such types of pulsations were detected (over 20 such pulsations were already detected by the end of 1958), 4 of which were of the drawn-out (train-like) type, 3 were classified as microbays, and 2 were of the pulse type. (see Figure).

The summary table (Table 2 - see pages 69-71) gives the beginning and end of the pulsations according to world and local time, maximum amplitudes of oscillations in gamma and millivolts, and the primary periods in seconds.

The Borok station is located in the central portion of the European USSR, Lovozero - in the North, in the zone of most frequent aurora polaris occurrence, Petropavlovsk-Kamachatskiy - almost on the shore of the Pacific Ocean, and the Simferopol' station in the Crimea is located 30 km from the shore of the Black Sea. Table 2 gives the relation (ratio) between the amplitudes of geomagnetic pulsations, occurring at the Lovozero, Petropavlovsk-Kamchatskiy, Tbilisi and Simferopol' stations, and the amplitude at the Borok station. In all cases, except one, these ratios are greater than one (unity), inspite of the fact that the geomagnetic latitudes of these stations differ sharply: Borok is located 6^{o} North of Petropavlovsk-Kamchatskiy, while Simferopol' lies 8^{o} South of Borok. Apparently, such an amplitude ratio can be explained by the fact that the amplitude of geomagnetic pulsations is smaller in the center of large continental massifs than at shore stations, where these amplitudes are associated with marine currents of considerable magnitude flowing in the vicinity of shore lines (this assumption must be checked in a special series of studies).

An analysis of the data listed in Table 2 has shown that the distribution of amplitudes of geomagnetic pulsations is not related to local time: amplitudes of different magnitude are observed with the same frequency at each station, both during daytime as well as at night. This may mean that simultaneously occurring pulsations are caused by electromagnetic movements taking place outside the ionosphere, and are practically not shielded by the latter.

Table 2

Date	Station	Geomagnetic Pulsation							
		World Time		Local Time		H_Z, gamma	T, sec.	$\frac{H_{ZP}}{H_{ZB}}$	$\frac{H_{ZL}}{H_{ZB}}$
		t_H, hr-min	t_K, hr-min	t_H, hr-min	t_K, hr-min				
7 Aug 1957	Borok	19-44	19-47	22-20	22-23	0.148	60	-	-
	Petropavlovsk--Kamchatskiy	~19-43	-	06-17	-	0.65	60	4.39	60.13
	Lovozero	19-41	19-45	22-01	22-05	8.9	90	-	-
	Simferopol'	-	-	-	-	-	-	-	-
4 Sept 1957	Borok	01-38	01-46	04-14	04-22	>0.25	480		
	Petropavlovsk--Kamchatskiy	01-38	01-47	12-12	-	2.61	~540		
	Lovozero	01-38	01-44	03-58	04-04	9	~300	<10.44	<36.00
	Simferopol'	01-37	-	03-53	-	0.08	60		
	Tbilisi (Dusheti)	01-38	01-44	04-37	04-43	~0.61	-	-	-
4 Sept 1957	Borok	-	-	-	-	-			
	Petropavlovsk--Kamchatskiy	01-54	-	12-28	-	1.4	90		
	Lovozero	01-54	-	04-14	-	9	70		
	Simferopol'	01-54	-	04-10	-	0.24	90		
7 Sept 1957	Borok	11-00	11-20	13-36	13-56	>0.252			
	Petropavlovsk--Kamchatskiy	11-04	11-16	21-38	21-50	1.229		<4.87	<12.2
	Lovozero	11-00	11-12	13-20	13-32	3.08			
	Simferopol'	11-00	-	13-16	-	2.75	720		
12 Sept 1957	Borok	~03-30	~03-56	06-06	06-30	0.174			
	Petropavlovsk--Kamchatskiy	~03-24	~03-52	13-58	14-26	-			8.85
	Lovozero	~03-30	~03-45	05-54	06-05	1.54			
	Simferopol'	03-22	-	05-38	-	2	720		
14 Sept 1957	Borok	~02-31	~02-42	05-18	05-29	≥0.15	90		
	Petropavlovsk--Kamchatskiy	~02-31	~02-40	13-05	13-14	1.18	80		
	Lovozero	02-31	~02-39	04-51	04-59	4.31	240	7.86	28.73
	Simferopol'	02-30	-	04-46	-	1	180		
17 Nov 1957	Borok	03-11	-	05-47	-	0.123	300		
	Petropavlovsk--Kamchatskiy	03-11	-	13-45	-	0.72	360	5.85	-
	Lovozero	-	-	-	-	-	-	-	-
	Simferopol'	03-11	-	05-27	-	0.2	-	-	-
	Tbilisi (Dusheti)	03-11	-	06-10	-	0.31	240		

(See legend on p. 68)

Table 2 (Concluded)

Date	Station	Geomagnetic Pulsation $\frac{H_{ZS}}{H_{ZB}}$	Geomagnetic Pulsation $\frac{H_{ZT}}{H_{ZB}}$	Earth Current Pulsation, World Time t_H, hr-min	World Time t_K, hr-min	Local Time t_H, hr-min	Local Time t_K, hr-min	E_{N-S} mv/km	E_{E-W} mv/km
7 Aug 1957	Borok	-	-	-	-	-	-	-	-
	Petropavlovsk-Kamchatskiy	-	-	-	-	-	-	-	-
	Lovozero	-	-	-	-	-	-	-	-
	Simferopol'	-	-	-	-	-	-	-	-
4 Sept 1957	Borok			01-38	01-47	04-14	04-23	3.04	11.41
	Petropavlovsk-Kamchatskiy			01-38	-	12-12	-	37.92	20.68
	Lovozero	∠0.32	<2.44	-	-	-	-	-	-
	Simferopol'	-	-	-	-	-	-	-	-
	Tbilisi (Dusheti)	-	-	-	-	-	-	-	-
4 Sept 1957	Borok			01-54	01-56	04-30	04-32	2.74	4.89
	Petropavlovsk-Kamchatskiy			01-55	-	12-29	-	26.07	21.62
	Lovozero	-	-	-	-	-	-	-	-
	Simferopol'								
7 Sept 1957	Borok			11-00	11-20	13-36	13-56	2.16	10.96
	Petropavlovsk-Kamchatskiy	<10.91		11-03	11-23	21-37	21-57	22.41	11.79
	Lovozero	-		-	-	-	-	-	-
	Simferopol'								
12 Sept 1957	Borok			03-27	03-47	6-03	6-23	3.32	8.61
	Petropavlovsk-Kamchatskiy	1.15		03-25	03-45	13-59	14-19	7.12	3.92
	Lovozero			-	-	-	-	-	-
	Simferopol'			-	-	-	-	-	-
14 Sept 1957	Borok			02-31	02-36	05-17	05-12	1.52	5.59
	Petropavlovsk-Kamchatskiy			02-30	02-40	13-04	13-14	42	12.75
	Lovozero	6.66		-	-	-	-	-	-
	Simferopol'			-	-	-	-	-	-
17 Nov 1957	Borok								
	Petropavlovsk-Kamchatskiy	1.63	2.52						
	Lovozero	-	-	-	-	-	-	-	-
	Simferopol'	-	-	-	-	-	-	-	-
	Tbilisi (Dusheti)								

(See legend on p. 68)

Table 2 Legend - Conventional designations: t_H - Onset time of oscillations; t_K - Termination time of oscillations; H_Z - Amplitude of vertical magnetic field component; E - Amplitude of the horizontal electrical field component; T - Period; H_{ZP} - Amplitude of vertical magnetic field component at Petropavlovsk-Kamchatskiy; H_{ZL} - Amplitude of vertical magnetic field component at Lovozero; H_{ZS} - Amplitude of vertical magnetic field component at Simferopol'; H_{ZT} - Amplitude of vertical magnetic field component at Tbilisi(Dusheti); H_{ZB} - Amplitude of vertical magnetic field component at Borok.

The most plausible explanation of this phenomenon is that simultaneously
occurring pulsations of short periods and low amplitudes (of the order of F
hundredths of 1 gamma and several gammas) are caused by the passage of the 4
earth through weak corpuscular streams, which the earth crosses while 9
travelling around the sun.

The passage of the earth through such corpuscular streams results in the formation of weak magnetic disturbances, which apparently are of a world-wide character. This assumption will be checked later on the basis of IGY data obtained at foreign stations, and will also be compared with corresponding characteristics of solar activity.

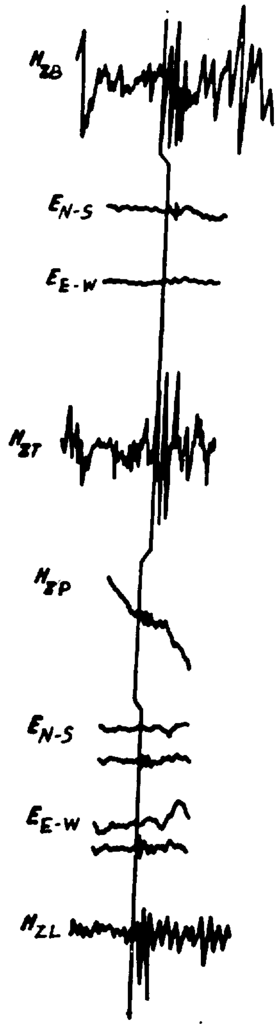

Figure 1.- Pulsation of the geomagnetic field and earth currents, which occurred on September 14, 1957.

H_{ZB} - Recording of H in Borok (t_H = 02 hr 31 min world time, amplitude A = 0.15 gamma); E_{N-S} - Recording of the meridional component of earth currents (t_H = 02 hr 31 min, A = 1.52 mv/km); E_{E-W} - Recording of the latitudinal component of earth currents (t_H = 02 hr 31 min, A = 5.59 mv/km); H_{ZT} - Recording of H_Z at Tbilisi (Dusheti) (t_H = 02 hr 31 min, t_K = 02 hr 41 min, A = 0.46 gamma); H_{ZP} - Recording of H_Z at Petropavlovsk-Kamchatskiy (t_H = 02 hr 31 min, t_K = 02 hr 40 min, A = 1.18 gamma); E_{N-S} - Recording of the latitudinal component of earth currents (t_H = 02 hr 30 min, A = 13 mv/km); E_{E-W} - Recording of the meridional component of earth currents (t_H = 02 hr 30 min, A = 4.2 mv/km) H_{ZL} - Recording of H_Z at Lovozero (t_H = 02 hr 31 min, A = 4.31 gamma).

Excitation of Short-Period Oscillations of the Geomagnetic Field During the Sudden Onset of Magnetic Storms (see Note)

By A. S. Dvoryashin

In connection with recent theoretical and experimental research on the density of interplanetary space (1-6), it is possible to state that the sharp change in the magnetic field occurring during the sudden onset of magnetic storms is caused by the passage of a shock wave (7-9) arising during a flare (10-13), or as a result of the movement of a corpuscular stream. In this connection, it is difficult to provide an explanation for the shock (impact) front in interplanetary space taking place under low density conditions, i.e., in case of great free path lengths. F 4 9

According to G. Sen (14), the front thickness of a strong shock wave (the velocity of magnetohydrodynamic sound in interplanetary space is equal to about 10^6 cm/sec, if $H \approx 10^{-5}$ gauss, and consequently, in case of a strong shock wave) is approximately equal to several free path lengths within the front range. The thermal velocities of ions behind the front of a strong shock wave are comparable in size with the macroscopic gas velocity. Therefore, the temperature behind the front, if the latter is formed, can be measured in several million degrees, and therefore the free path length, determined by the expression (15):

$$\lambda = \frac{5(kT)^2}{2\sqrt{2}n_i Z^4 e^4 A_2(2)}$$

where:

$$A_2(2) \approx 4 \ln \frac{4kT}{n^{1/3}{}_i{}^2}$$

is of the order of $3 \cdot 10^{15}$ cm, if $n_i \approx 10^3$ cu.cm. and $A_2(2) \approx 90$.

The mean temperature within the limits of the front is considered to be equal to the arithmetic mean of its initial and final values, and $\frac{1}{6} m_i v^2$ is substituted for kT. The magnitude thus obtained ($\lambda = 3 \cdot 10^{15}$ cm) is considerably greater than the magnitude of the thickness of the

(Note: The author wishes to express his gratitude to S. B. Pikel'ner for reviewing and discussing the work described in this article).

disturbance front, which is to be expected as a result of the duration of the sudden onset. Consequently, under the conditions selected, it does not appear possible to furnish an explanation for the sharp field increase occurring during a sudden onset.

It can be demonstrated that the formation of a sharp front can only take place when the magnetic field and a final, but sufficiently high, conductivity are taken into account, since in this case, the depth of the front will also be determined by electromagnetic dissipation mechanisms and, under certain conditions, can be considerably smaller than λ .

The depth of the front, when λ is considerably greater than Larmor's radius, as is the case in interplanetary space, has not yet been accurately computed. In a simplified case of a medium with an isotropic conductivity
F 4 9 (16), the depth of the front is several times greater than the magnitude:

$$\lambda = \frac{c^2}{4\pi\sigma a_1}, \quad \text{(see Note)}$$

where σ is the conductivity, $a_1 = \sqrt{\frac{\gamma p_1}{\rho_1}}$ is the sound velocity, and, in case of a very high conductivity, the front of the jump must be sharp. (Note: After this study was completed, the author received the article published by Kato and Saito (40), describing pulsations accompanied by ssc). The conductivity of interplanetary space is of the order of 10^{11} esu (electrostatic units), if $T \approx 10^3$ degrees K, and if, according to Chapman (5), T is assumed to be equal to about 10^5 degrees K, then $\sigma = 10^{14}$ esu. In both of these extreme cases, an exceptionally sharp front of the jump is obtained, which is equal to less than 10^4 cm. Of course, under low density conditions, when the conductivity is anisotropic, a different numerical magnitude may be obtained, but the above estimate still points to a sharp change of the field within the limits of the jump.

The incidence of the shock wave (with a velocity of 1,500 km/sec) upon the ionized medium (17-19) in the geomagnetic field is equivalent to an impact upon an elastic medium. The magnetic field will act in the same way as a shock absorber (buffer), upon which the wave will impinge. It is to be expected that oscillations of the medium together with the "frozen-in" magnetic field will occur, which must propagate in the same way as magnetohydrodynamic waves.

A special study of the fine structure of the variations in the magnetic field during a sudden onset of magnetic storms, undertaken by the author for this purpose, and which is being conducted at the Crimean Astrophysical Observatory with the aid of a fluxmeter unit (Figure 1), actually led to the detection of short-period oscillations of the magnetic field (SPO during ssc), which are excited during the sudden onset of magnetic storms (Figures 2, 3 and 4) (See Note). (Note: After the present work was completed, the author received the article published by Kato and Saito (40), describing pulsations accompanied by ssc.)

A study of SPO during ssc reveals the following most characteristic properties of these oscillations:

1. The sign of the first oscillation is always positive and corresponds to a field increase.

2. The amplitude of the first oscillation is generally the highest one, and is equal, on an average, to A $\simeq$0.2-0.1 gamma.

3. The oscillation period is equal to 12-15 seconds.

4. The SPO's undergo attenuation (damping) during a period of 1-2 minutes.

5. The excitation of SPO in case of ssc depends upon the time of the day (24-hour period).

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Obviously, in order to interpret this phenomenon, it is necessary to have recourse, as was done by Dungey (20), to magnetic hydrodynamics; this has already been done in a number of studies (21-23), devoted to an explanation of pc and pt-type oscillations (see Note) i.e., the propagation path of the wave must be limited by the reflection arising, for example, during a rapid increase in electron density n_e. (Note: Designations adopted by the International Association for Geomagnetism and Aerial Terminology (see the article by V. A. Troitskaya in the IGY Information Bulletin, No 4.) Knowing the propagation velocity of the wave, it is possible to derive the wavelength, which is comparable to the dimensions of the system, from the oscillation period T. The velocity of an Alvin (or Alfven?) wave depends on the magnitude of ρ. On the basis of a comparison between the oscillation period and the free path time in the D, E and F layers of the ionosphere, it follows (24) that, at the rate of ionization which takes place in the ionosphere, neutral atoms cannot be carried away by the wave, and therefore the velocity of magnetohydrodynamic waves is determined only by the density of the plasma, i.e., by the ionized portion of the gas. Neutral atoms at first do not participate in the movement, and later their role merely involves the quenching of oscillations and the conversion of the wave energy into heat ("friction losses") (25-28). Consequently, at a ion concentration $n_i \simeq 10^3$ cm^{-3}, the propagation velocity of an Alvin wave $V \simeq 2.10^8$ cm/sec, if H = 0.03 gauss. By assuming an average SPO period of about 15 sec, we find that the wavelength L = VT = 30,000 km. This means that the oscillating system cannot be limited by fluctuations of the density in the ionosphere, as in another case of giant pulsations, observed in Polar latitudes. The latter was suggested by Lehnert (29). The magnitude obtained exceeds the diameter of the earth, and we naturally reach the conclusion that the wave is propagated along a line of force supported by the ionosphere at geomagnetically conjugate points, and is consecutively reflected by the ionosphere at both ends of the line of force. During the course of each reflection, a certain portion of energy may travel through the ionosphere, thus yielding the observed SPO's.

The attenuation (damping) of oscillations may in principle be caused both by such a seepage as well as by Joule (30) and "friction" losses (25-28). It can be easily shown that Joule losses are insignificant in case of a period of several score seconds. Friction losses in interplanetary space are small in view of the relatively low content of neutral atoms. However, such losses may be substantial in case of seeping (leaking) waves travelling through the ionosphere. The basic mechanism of transfer from ions to neutral atoms will involve a charge-exchange (the cross-section of an elastic collision is smaller), whereby the attenuation time of the wave will be determined by the magnitude of the charge-exchange time. The path length$^{(1)}$ of an ion, prior to charge-exchange, is equal to about 10^7 cm in the F-2 layer, and to 2.10^5 cm in the F-1 layer. The possible formation of stable standing magnetohydrodynamic waves in the F-1 layer is limited by the small value of 1 in this layer, since the time elapsing prior to charge-exchange amounts to several seconds.

No substantial attenuation (damping) due to interaction with the neutral gas should take place in the proposed model, since the bulk of the standing wave is located at a considerably higher altitude than the F-2 layer. In the F-2 layer itself, oscillations may be sustained by the magnetic energy transmitted along lines of force by layers located at higher altitudes. A wave travelling through the F-1 layer will not have time to become attenuated, since it is propagated with a velocity $V \simeq 5.10^7$ cm/sec, i.e., it will run through the layer in about 0.2 seconds. During this time, an oscillating ion will cover a distance of about 2.10^4 cm, i.e., a charge-exchange will not have time to occur. In the E layer, the transmission time of the wave is longer than the charge-exchange time, and this fact constitutes a difficulty for the proposed hypothesis. However, a similar difficulty is experienced in connection with any other kind of hypothesis concerning the formation of short-period oscillations.

It can be assumed that the dissipation of the energy of these magnetohydrodynamic waves represents a source of warmup (of the external atmosphere) and is the cause of acceleration of charged particles to an energy of several score (and hundreds) kev (kiloelectron - volts), observed in satellites (31, 32) and rockets (33, 34).

It should be noted that the explanation of SPO's, in case of the presence of ssc, does not necessarily require the presence of a shock wave. In principle, the excitation of SPO's can be achieved by means of the commonly studied Chapman-Ferraro flux, if one assumes that this flux consists of separate corpuscular clouds (as evidenced by the character of magnetograms), carrying "frozen-in" magnetic fields. The existence of such "frozen-in" fields in fluxes can be deduced from a study of the variations in the intensity of cosmic radiation (35, 36), which are precisely connected with storms taking place in the presence of ssc, and also from general energy considerations (37). The SPO's observed during a magnetic field disturbance (bay with pulsations) can be explained as being due to the excitation of magnetohydrodynamic waves under the impact of individual corpuscular "condensations", carrying "frozen-in" magnetic fields; the interaction of these magnetic fields with the magnetic field of the earth has been studied in (38, 39).

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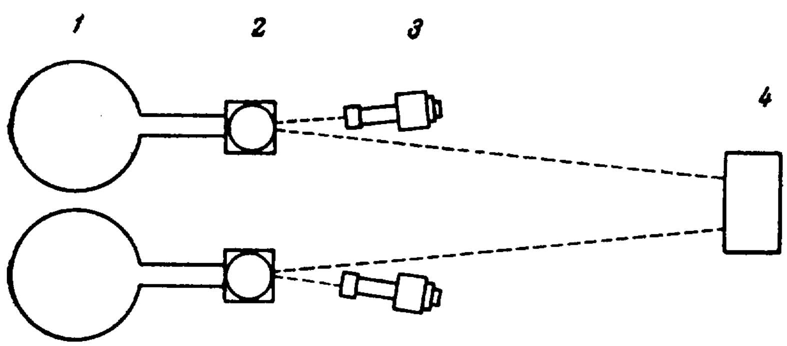

Figure 1.- Diagram of the fluxmeter unit at the Crimean Astrophysical Observatory. 1 - induction circuit; 2 - fluxmeter; 3 - illuminator 4 - recorder.

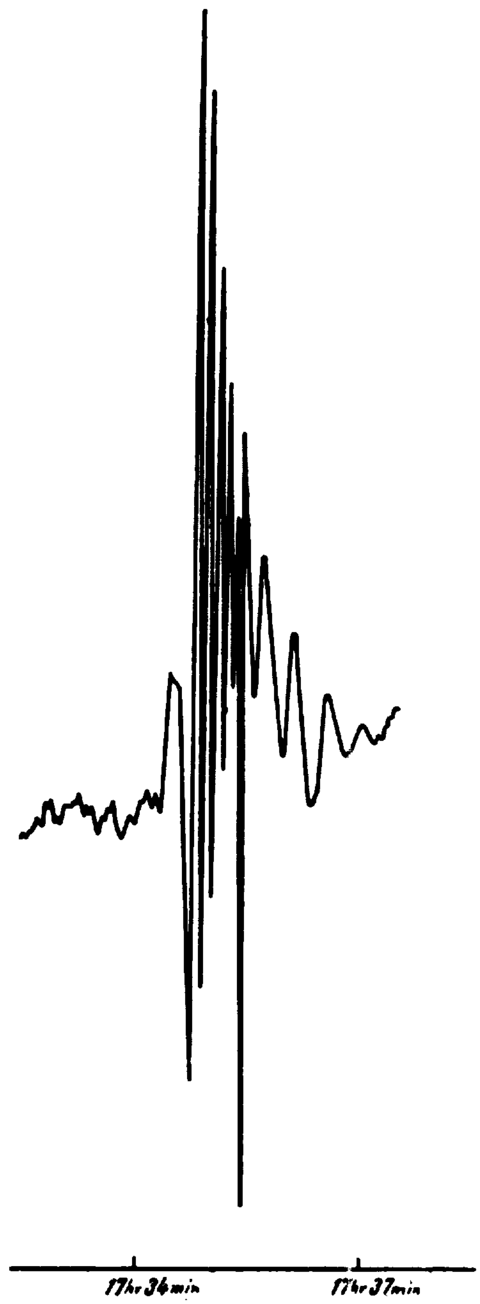

Figure 2.- SPO's excited during the sudden onset of a magnetic storm on April 17, 1957.

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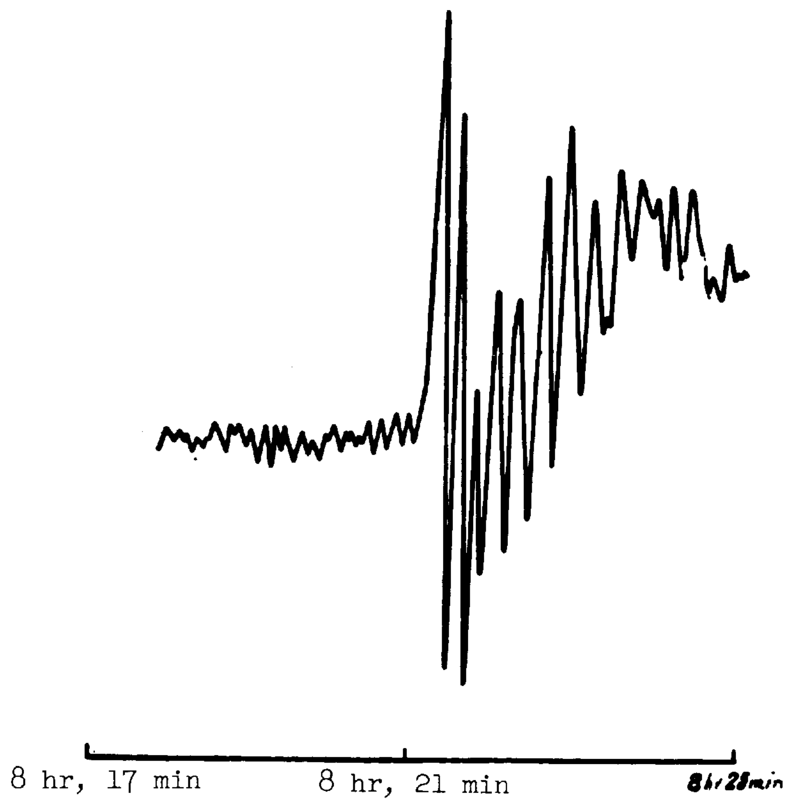

Figure 3.- SPO's excited during the sudden onset of a magnetic storm on May 30, 1957.

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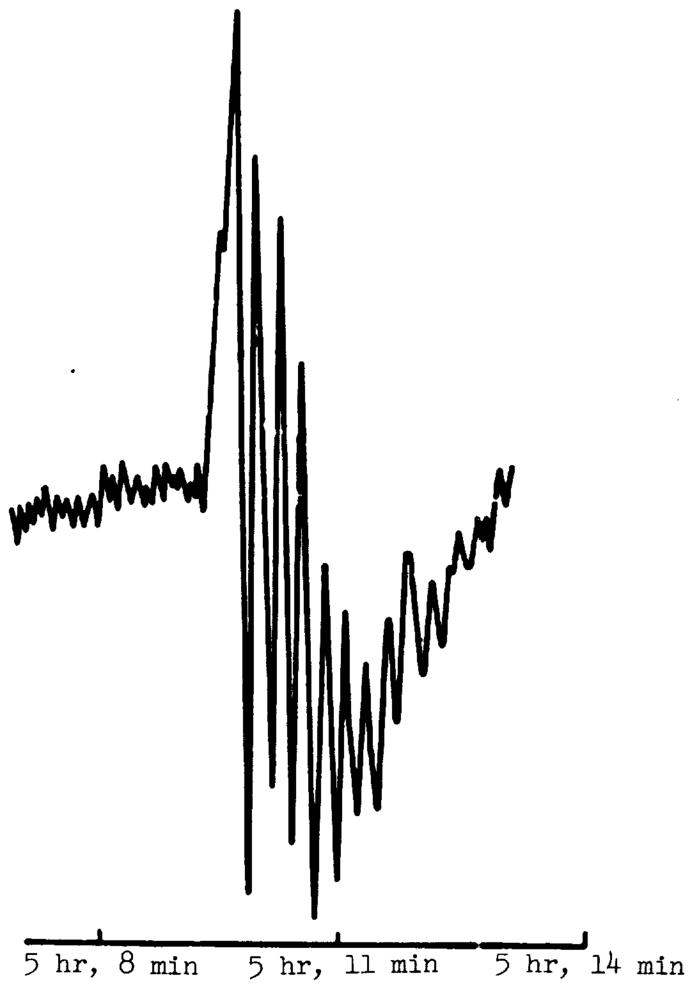

Figure 4.- SPO's excited during the sudden onset of a magnetic storm on August 6, 1957.

Certain Peculiarities of A Variable Geomagnetic Field in the Region of the Mirnyy South Pole Observatory

By S. M. Mansurov

When the first magnetograms were obtained at the Mirnyy South Pole Observatory, an unusually great variation in the vertical component was noted, as well as the fact that the K-variation of this component almost always systematically exceeded the K-variations of both horizontal components.

F49 No such phenomena were ever observed at any other permanently operating magnetic observatory in the Soviet sector of the Arctic, or at any temporary magnetic stations located on drift ice in the central Arctic Basin.

The magnetic pavilion at Mirnyy is built on a crystalline rock outcrop 50 meters from the edge of the ice barrier, and it is possible that these rock formations could have exerted an induction effect.

For this reason, recordings were made with the aid of a portable (field) variational station at several points near the magnetic pavilion and at distance of 13 kilometers inland from the pavilion as well as on a land floe in the sea.

As a result of these additional recordings, it was possible to establish the presence of an unusually great horizontal gradient of the K-variation in the vertical declination component near the magnetic pavilion, and a considerable decrease in the variation of the vertical component at points located at a great distance both inland and out in the sea from the magnetic pavilion. The variability of the vertical component is caused by the attenuation of small short-period oscillations, while the general characteristics of variations at all temporary registration points remained completely similar to the variations recorded in the magnetic pavilion.

As was established, magnetic anomalies caused by outcrops of native crystalline rock formations in the Mirnyy region do not exceed 1,000 gamma in H and Z. The magnetic susceptibility of these rocks was found to be equal to $2{,}500 \cdot 10^{-6}$ CGS.

Simple computations have shown that the peculiarities of the variable geomagnetic field discovered in the area of the Mirnyy South Pole Observatory cannot be attributed to the induction effect exerted by crystalline rocks. Another explanation had to be found, which could be associated in some manner with the amazing similarity, also discovered at Mirnyy, between the irregular portion of variations in the vertical component and variations of telluric currents (Figure 1). This similarity does not occur only during a few daytime hours, corresponding to a period of maximum magneto-ionospheric disturbance in this region.

Since a certain regularity was noted in the change of amplitudes of the K-variations only in case of the vertical component and the declination, while no peculiarities were observed in the behavior of the horizontal component, the character of the changes occurring in the amplitudes of the K-variations in relation to the location of the point of observation was studied in greater detail in the direction of the first magnetic vertical from the magnetic pavilion by means of field variational stations and visual observations during disturbances at BMZ and QHM (declinational variations were observed at QHM). In this connection, the following patterns (laws) were established (Figure 2).

1. Amplitudes of the irregular portion of geomagnetic variations were approximately of the same magnitude at a distance of 2.5 km inland from the shore and at a distance of 10 km out in the sea. These amplitudes were considered as normal amplitudes.

2. Progressing from inland towards the shore, the amplitudes of the K-variations of the vertical component gradually increased and reached their highest value, which was 30% higher than the normal value, in the immediate vicinity of the shore. Then, as one moved out into the sea from the shore, these amplitudes started to decline sharply and reached a normal value at a distance of 300 meters from the shore. As one moved further out into the sea, the amplitudes fell below the normal. A second extreme point is located 1 km from the shore at which the amplitudes of the K-variations of the vertical component are 15% below normal. Upon moving further away from the shore, the amplitudes gradually begin to rise toward their normal value.

3. Along this same cross-section, the change in the amplitudes of the K-variations of declination exhibits only one extreme point, located 300 meters off-shore. At this point, the amplitudes of the declinational variations are 30% higher than the normal values. While moving from the shore toward this point, the amplitudes rise sharply, and then drop slowly, approaching their normal values, upon moving further away towards the sea.

4. No such sharp and regular changes in the amplitudes of the K-variations of the horizontal component were observed in this cross-section.

It is necessary to recall that the declination is equal to $-78^{\circ}.5$ in the Mirnyy region, and that the first magnetic vertical coincides approximately with a line perpendicular to the shoreline in this area.

While plotting the above-mentioned curves showing the relation between the values of amplitudes of K-variations and the location of the point of observation, we measured primarily the amplitudes of elementary disturbances (at Mirnyy, sharply expressed elementary disturbances at Z and D bear opposite signs). In view of this fact, we were able to use curves showing variations in the amplitudes of K-variations in performing a harmonic analysis of the results of observations conducted in the above cross-section, in which the variable field was subdivided into an external and an internal section, whereby these curves were first associated with an elementary disturbance of medium magnitude
F49 ($\Delta Z_0 = 160\gamma$, $\Delta D = 90\gamma$), recorded in the magnetic pavilion of the Mirnyy South Pole Observatory.

An analysis showed that the internal field section of disturbances is approximately 2 times larger than the external field section in Mirnyy region.

The cause of such an unusual relation can hardly be located at any considerable depth below the surface of the earth. The shore effect in the geomagnetic variations discovered at Mirnyy is no doubt due to an ocean-induced electric current, which exhibits an abnormally high density along the shore line.

We were able to obtain a direct proof of this fact by means of a direct recording of marine electric currents. At a distance of 10 kilometers from the shore, the variation vector of the current potential gradient in the sea, was found to be smaller by nearly one order of magnitude than in the direct vicinity of the shore, in the area of the Mirnyy Observatory.

It should be expected that the shore effect in geomagnetic variations is to be observed everywhere in various degrees along the borderline between the ocean and the land. Depending on the predominant direction of currents induced in the sea, the greatest effects in geomagnetic variations will be found either in areas of capes protruding into the sea or in areas where straits or deep bays are present.

In view of the extensive use of data obtained at magnetic observatories, it is suggested that, during quantitative estimates of many geophysical processes and constants, all shore magnetic observatories (especially those located in polar and equatorial regions, where inductive ionospheric current systems are particularly intensive), conduct a detailed study of the nature of geomagnetic variations and earth currents during the next few years, in order to obtain quantitative estimates of the shore effect in the area of every magnetic observatory.

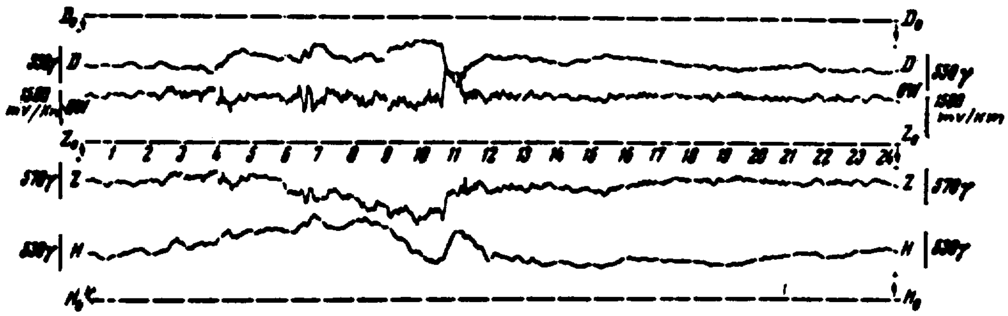

Figure 1.- Diurnal magnetogram obtained at the Mirnyy Observatory on January 1, 1958. D - declination; H - horizontal component; Z - vertical component of geomagnetic variations; OW - eastern component of the variations of telluric currents.

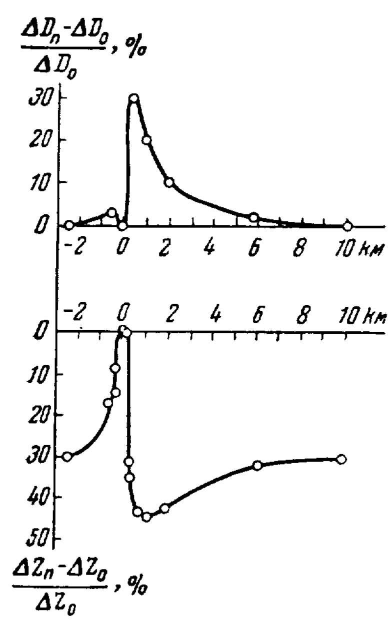

Figure 2.- Change in the value of amplitudes of the irregular portion of declinational variations ΔD and of the vertical component ΔZ depending upon the location of the recording point in relation to the shoreline.

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Behavior of the Ionosphere During Sudden Ionospheric Disturbances

N. A. Savich

Relative variations in electron concentration during sudden ionospheric disturbances, due to the active radiation of solar flares, are described by the ionization formula:

$$\tau_0 \cdot \frac{d}{dt} \cdot \frac{N(t)}{N_0} = \frac{I(t)}{I_0} - \left[\frac{N(t)}{N_0}\right]^2 , \qquad (1)$$

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where N_0 and I_0 are the values of electron concentration and of the ion-formation function at the moment of onset of the ionospheric disturbance, and $\tau_0 = 1/\alpha N_0$.

A solution of formula (1) for the function $I(t)/I_0$ was previously obtained in the form of a square impulse [1, 2]. If the ion-formation function is a linear time function, i.e., $I(t)/I_0 = P_0 + \frac{t}{T}$ (T - time during which function $I(t)/I_0$ varies by one unit), then the solution of equation (1) takes the form of:

$$\frac{N(t)}{N_0} = \frac{1}{\beta^{1/3}} \cdot \frac{[v^{10} - a\beta^{1/3}v^0] \cdot u' - [u^{10} - a\beta^{1/3}u^0] \cdot v'}{[v^{10} - a\beta^{1/3}v^0] \cdot u - [u^{10} - a\beta^{1/3}u^0] \cdot v}, \qquad (2)$$

where $\beta = \frac{T}{t_0}$ and $T > 0$ or $T < 0$ respectively for a growing or decreasing function $I(t)/I_0$; $a = \frac{N(0)}{N_0}$ for variation sectors of the ion-formation function with different T values; u, v, u', and v' are Eyri (? or Airie) functions and their derivatives [3] with the arguments $Z = \beta^{2/3}\left(P_0 + \frac{t}{T}\right)$; u^0, v^0, u^{10}, and v^{10} are Eyri (Airie?) functions and their derivatives with the arguments $Z_0 = \beta^{2/3} P_0$.

Let us examine certain applications of the above relations. Occasionally, a comparison is made between sudden ionospheric disturbances and the development course of flares in light $H\alpha$; or the lag (retardation) of the maximum ionospheric effect in relation to the maximum brightness of the flare in $H\alpha$ is determined [4, 5]. In this connection, an attempt was made to check the hypothesis concerning the extent to which the development of flare in $H\alpha$ is characteristic for active radiation. The flare development curves (the time course of brightness and radiation flow in $H\alpha$) were approximated by broken lines.

Assuming that the active radiation of the flare varies in time in the same way as the brightness or radiation flow of the flare vary in Hα, but with a greater amplitude, variations of electron concentration were computed with the aid of Formula (2) for the flares of 31 August 1956, 28 August, 3 September, and 23 November 1957, wherein τ_0 was assumed to be equal to 4,000 seconds [6]. For purposes of comparison with an experiment involving measured f-min values, variations of electron concentration [6] were computed. Figure 1 shows, as an example, a comparison between the experimentally determined course of $N(t)/N_0$ and the course computed by the above method in case of flares. Such a comparison shows that in case of the given τ_0 value the development of the flare in Hα does not characterize the changes in active radiation.

In this connection, the reverse problem becomes important. In case of continuous measurements of $N(t)/N_0$ during a disturbance (for instance, in case of measurements of f-min in the D-region, etc.,), it is possible to determine the ionospheric parameter τ_0 and the time course of the active radiation which caused the disturbance. Assuming that the active radiation of the flare, in its initial stage of development, may be approximated sufficiently well by a triangular pulse, then it is possible to determine both the value of τ_0 as well as the time lag, t_m, of the maximum electron concentration in relation to the apex of the approximating triangle. The following three basic parameters of this triangle are also determined: T_0 and T_1 which stand, respectively, for the growth and fall-off velocity of function $I(t)/I_0$ on various sides of the triangle, and t_0, i.e., the total rise time of function $I(t)/I_0$, which determines its maximum value. The following 5 equations are required for this purpose:

$$\frac{N_m}{N_0} = \psi(T_0, t_0, T_1, t_m, \tau_0), \tag{3a}$$

$$\frac{N_m}{N_0} = \sqrt{1 + \frac{t_0}{T_0} + \frac{t_m}{T_1}}, \tag{3b}$$

$$\theta = t_0 + t_m, \tag{3c}$$

$$\frac{d^2}{dt^2}\left(\frac{N}{N_0}\right)_{t=0} = \frac{1}{\tau_0 T_0}, \quad T_0 > 0 \tag{3d}$$

$$\frac{d^2}{dt^2}\left(\frac{N}{N_0}\right)_{t=t_m} = \frac{1}{\tau_0 T_1}, \quad T_1 < 0. \tag{3e}$$

Equation (3a) is actually equation (2) for the moment, t_m, of maximum electron concentration. Relationship (3b) is derived from the maximum condition

$$\frac{d}{dt}\left(\frac{N}{N_0}\right)_{t = t_m} = 0.$$

The magnitude θ in (3c) is the time interval between the beginning of the disturbance and the moment of maximum electron concentration. The computation of second derivatives from $N(t)/N_0$ yields equations (3d) and (3e), corresponding to the moments $t = 0$ and $t = t_m$, whereby the left members of these equations are obtained from the experimental graph of $N(t)/N_0$. By solving the system of equations (3), the value of τ_0 is obtained; then, with the aid of equation (1) and the experimental graph of $N(t)/N_0$, one determines the time course of the function $I(t)/I_0$, which is proportional to the relative change of the active radiation of the flare. It should be noted that, in order to use this proposed method of computation, the experimentally determined course of $N(t)/N_0$ should be uninterrupted and relatively smooth during the ionospheric disturbance; this can be achieved by rounding off the measured values. As an illustration of the use of the proposed method, Figure 2 shows the results of the computation of function $I(t)/I_0$ for the flare of 28 August 1957. Changes in electron concentration were determined on the basis of f-min values and a "smoothened" curve was used for the computation. The obtained value of τ_0 was found to be equal to 4,800 sec., and $t_m \approx 600$ sec.

Thus, based on the consideration of unsteady processes occurring during sudden ionospheric disturbances, a method is proposed for determining the value of τ_0 and the time course of the active radiation of solar flares in the ionosphere.

It appears possible to use this proposed method in determining the effective recombination factor according to the diurnal course of the critical frequencies in various layers.

In the future, it will be interesting to compare such an analysis of sudden ionospheric disturbances with data on roentgen radiation of flares obtained by earth satellites.

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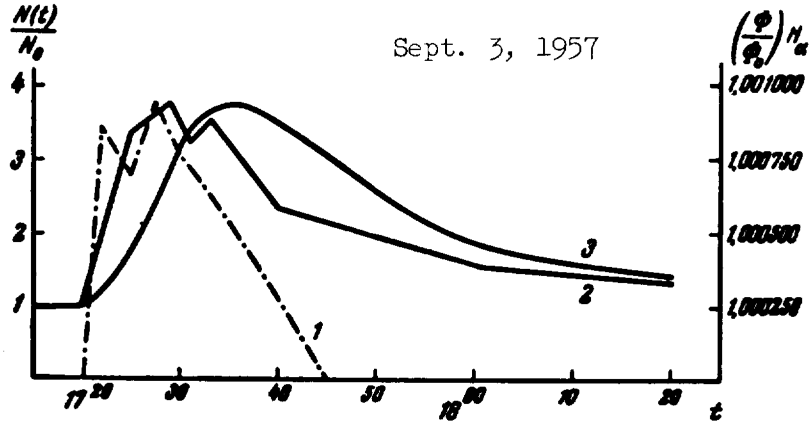
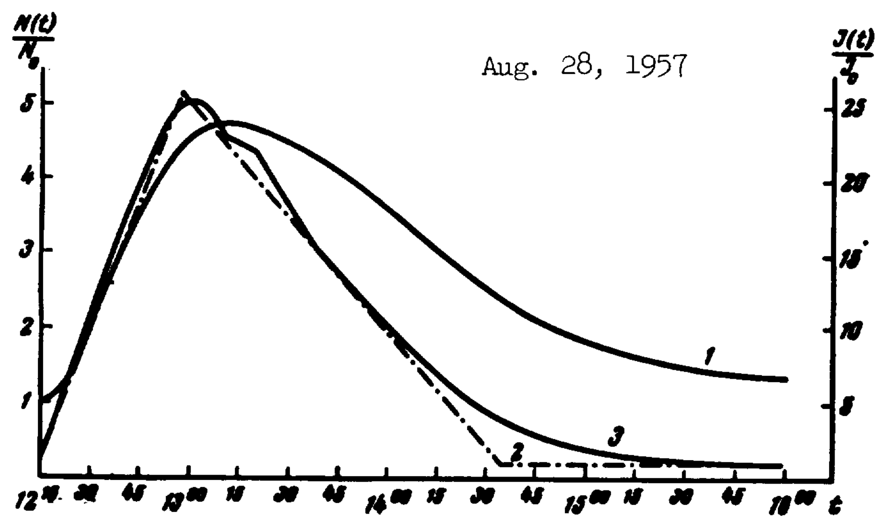


1 - Change in the radiation flow $\Phi(t)/\Phi_0$ of the flare in H_α.

2 - Change of $N(t)/N_{0/exp}$ determined according to f-min.

3 - Computed change of $N(t)/N_{0/theor}$.

Figure 1.- Comparison of the experimental and the theoretically computed change in electron concentration. Moscow time; $\tau_0 = 4{,}000$ sec.



1 - Smoothened curve $N(t)/N_{0/exp}$.

2 - Approximating function triangle.

3 - Change in $I(t)/I_0$, computed by means of formula (1) when $\tau_0 = 4{,}800$ sec.

Figure 2.- Variations of the ion-formation function $I(t)/I_0$ during the flare of August 28, 1957.

1957 July-December	0.56	3.03	37.12	1.88	258.8	9	9	2	5
1958									

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The mean monthly value of the K-index of K_m, the mean monthly amplitude A corresponding to K_m, the mean monthly 3-mark factor C, and the mean monthly value of the u-measure, all indicate the presence of a significant maximum in September 1957 (Table 1 and Figure 2). The maxima recorded on June 1957 and July 1958, which are almost comparable to the activity during the equinox periods, and the high activity during winter months, are unusual factors in the annual activity course.

The semi-annual values of the above characteristics are typical examples of the increase in magnetic activity. The semi-annual values of C, K, and A increased systematically up to the middle of 1958, when they reached their maximum value.

During the second half of 1957, the semi-annual u-measure and the semi-annual W number reached their highest values, which were equal, respectively, to 1.88 and 258.8, after which the semi-annual u-measure started to decline. In the second half of 1958, the semi-annual W number again rose to 250.0, as compared to the 220.3 value during the first half of 1958.

The magnetic activity of an individual month may be judged on the basis of one of the characteristics, K_m, A or C. This activity is confirmed by the data presented in Table 1. Therefore, only K_m is shown graphically (Figure 2).

The broken curves shown in Figure 2 are based on mean monthly values of the K-index in the Arctic and Antarctic, and at all stations in the Soviet Union.

The K-indices for the Arctic were derived from data obtained at Tikhaya Bay, Cape Chelyuskin, Murmansk, Dikson, Uelen and Tiksi; the K-indices for the Antarctic were derived from data obtained at Mirnyy, Oazis, Vostok and Pionerskaya.

It is interesting to compare the activity in the following manner.

If separate smooth curves showing the K-index for the Arctic and the Antarctic are drawn through individual minimum points, or near such points, while at the same time keeping in mind the total activity of K_m, then the activity in the Arctic and Antarctic can be divided into two parts. One part consists of a wave with an annual period, and the other part consists of individual disturbances superimposed on this wave. The resultant waves are in counter-phase and have different amplitudes, namely 0.5 mark for the Arctic and 0.8 mark for the Antarctic. Both waves correspond to the duration of daylight illumination at a given point on the earth, i.e., to the variation of an angle formed by the earth's rotation axis and a straight line between the sun and the earth.

The K_m activity is well reflected by disturbances in the Arctic and Antarctic.

An analysis of the monthly sums of individual K-index marks during the course of a year at the Mirnyy and Tikhaya Bay stations showed that the annual wave may be represented by marks 4, 5 and 6 at Mirnyy and marks 5 and 6 at Tikhaya Bay.

Mean monthly K-index values in Moscow yield only disturbances that correspond fully to K_m, while a wave is absent. Consequently, we are confronted here with a polar effect of activity.

It follows from a comparison of the K-indices in the Arctic and in the Antarctic that the scale of the K-index in the Antarctic, selected on the basis of the scale in Tikhaya Bay, is somewhat too high, particularly in regard to Pionerskaya station.

The annual K-index course for individual stations in the Antarctic (Table 2) is represented by parallel curves, located in relation to each other according to geomagnetic latitudes (Mirnyy $\Phi = 77.0$; Oazis $\Phi = 77.7$; Pionerskaya $\Phi = 80.5$; Vostok $\Phi = 89.2$).

The K- and Q- indices of Mirnyy (Table 2) are parallel in their mean monthly course, with a rise in K.

The new Q-index of magnetic activity constitutes a more detailed characteristic, but apparently does not differ substantially from the K-index during statistical computations over a long period of time.

Table 2
Mean Monthly Values of K-Indices in the Arctic and Antarctic and at Individual Antarctic Stations, and Q-Index of Mirnyy.

Month	1957							1958						
	Mirnyy	Oazis	Vostok	Pionerskaya	Antarctic	Arctic	Q-Index at Mirnyy	Mirnyy	Oazis	Vostok	Pionerskaya	Antarctic	Arctic	Q-Index at Mirnyy
January	-	-	-	-	-	3.3	-	4.2	3.7	3.8	3.0	3.7	3.6	3.9
February	-	-	-	-	-	3.5	-	4.4	4.4	3.8	3.0	3.8	4.3	4.1
March	-	-	-	-	-	4.0	-	4.0	3.9	3.3	2.8	3.5	4.5	3.7
April	-	-	-	-	-	4.1	-	3.1	3.0	2.5	2.0	2.6	4.1	3.0
May	-	-	-	-	-	3.6	-	2.9	2.6	2.3	1.8	2.4	4.0	2.3
June	-	-	-	-	-	4.1	-	2.8	2.5	2.1	1.8	2.3	4.2	2.5
July	2.9	2.2	-	2.3	2.5	3.6	2.4	3.3	2.8	2.4	2.1	2.6	4.3	3.0
August	2.9	2.5	-	2.0	2.4	3.4	2.2	3.0	2.6	2.2	2.2	2.5	3.8	2.5
September	3.8	3.4	-	2.6	3.3	4.2	3.4	2.8	2.7	2.3	2.2	2,5	3.2	2.6
October	3.8	3.2	-	2.5	3.2	3.5	3.3	3.3	3.1	2.7	2.4	2.9	3.3	-
November	4.4	3.8	-	3.0	3.7	3.7	4.1	3.3	3.0	2.9	2.7	3.0	2.8	-
December	4.6	4.1	-	3.3	4.1	3.8	4.2	-	-	-	-	-	-	-

On the basis of data obtained at magnetic observatories in the USSR, it would be expedient to compile a log of magnetic activity which would include the following items:

1) A list of observatories;
2) Lower limits of the K-index scale;
3) Amplitude range of magnetic storms;
4) A three-hour K-index;

5) A Q-index based on data of individual polar observatories;
6) A listing of magnetic storms;
7) A listing of bay-like magnetic disturbances;
8) A list of quiet and disturbed days.

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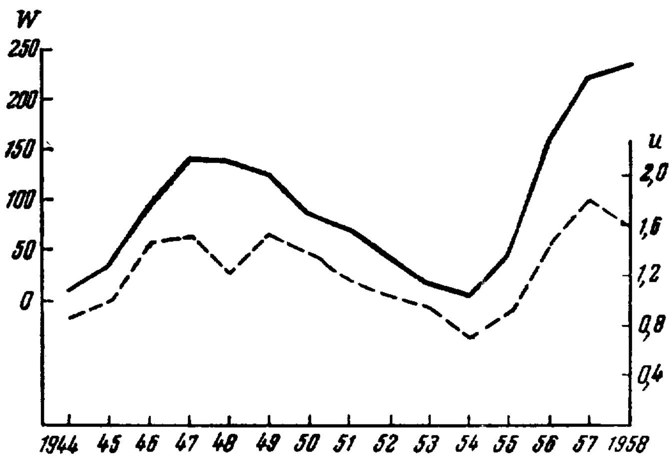

Figure 1.- Mean annual values of the u-measure (broken curve) and of the relative number of sun spots W (solid curve).

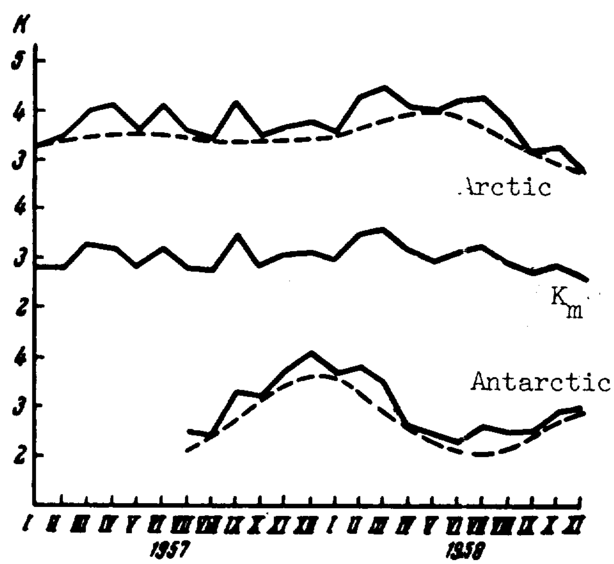

Figure 2.- Mean monthly values of the K-index in the Arctic and Antarctic, and at all stations in the Soviet Union (K_m).